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... the journal of cinematic illusions

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More War. 64

In Walt Disney Studios' epic *Pearl Harbor*, producer Jerry Bruckheimer and director Michael Bay stage a tale of love and valor against the backdrop of World War II and the infamous Japanese air attack on the U.S. Pacific Fleet that spelled the end of the country's isolationist doctrine. Depictions of the assault, along with earlier reenactments of air battles over Britain and the retaliatory Doolittle raid on Tokyo, were achieved through extensive use of digital battleships and planes—compliments of Industrial Light & Magic—in combination with large-scale mechanical and pyrotechnic effects by John Frazier and his crew. Stan Winston Studio contributed makeup effects. *Article by Jody Duncan.*

Accelerated Evolution 102

Echoing the sensibilities of his earlier comedy hit *Ghostbusters*, director Ivan Reitman's newest film, *Evolution*, has scientists battling aliens after a meteor crashes into the Arizona desert, releasing minute extraterrestrial lifeforms that vaguely attempt to mimic earth's evolutionary cycle. Phil Tippett and his Tippett Studio artists designed and created, through digital character animation, much of the continuously metamorphosing extraterrestrial ecology, from single-cell microorganisms to complex air and land creatures. Also in the mix were digital effects by Pacific Data Images and practical creature work by KNB EFX Group and Amalgamated Dynamics. *Article by Brad Munson.*

Moulin Rouge: Paris By Numbers 15

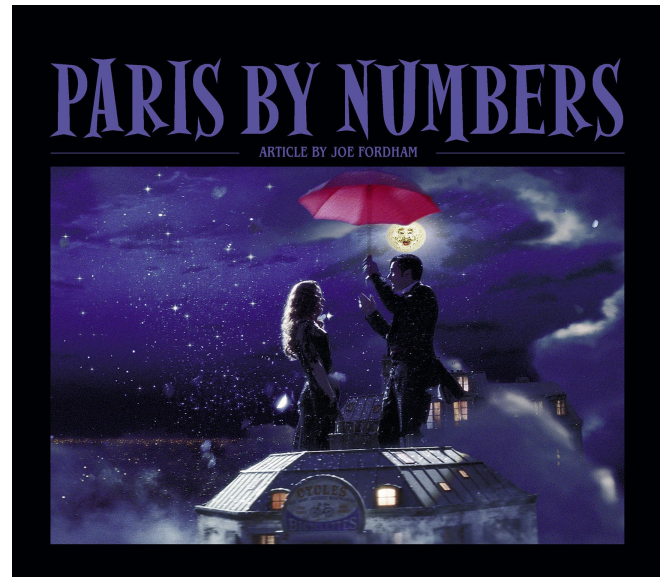
Final Fantasy: Flesh For Fantasy 33

Driven: Speed Demons 49

COVER—Japanese warplanes wreak havoc on the Pacific Fleet in *Pearl Harbor*.

PARIS BY NUMBERS

ARTICLE BY Joe Fordham



Named after a distinctive landmark that dates back to the reign of Louis XIV, when the hills of Montmartre were dotted with windmills, the Moulin Rouge- ‘red windmill’- in Paris still stands as an emblem for everything that is quintessentially French, and quintessentially naughty. Founded in 1889, at the height of the Art Nouveau movement and the industrial revolution, the cabaret quickly developed a reputation for its bawdy displays of lurid entertainment and high-kicking dancers, eclipsing the Folies Bergère and the Casino de Paris. Fueled by the Paris Universal Exhibition, the opening of the Eiffel Tower and the burgeoning resident artist community, the Moulin Rouge’s popularity flourished as celebrities, artists and socialites, high and low, flocked to embrace its illicit charms.

Over the past century, the Moulin Rouge has been immortalized by one of its most noted patrons, artist Henri de Toulouse-Lautrec, and by nearly two dozen disparate films. A 1922 silent film, *Woman to Woman*, showcased the nightclub in a set designed by a young Alfred Hitchcock. A 1934 comedy, titled *Moulin Rouge*, featured then bit player Lucille Ball in the chorus line. In 1953, John Huston brought the world his *Moulin Rouge*, an Oscar-lauded study of Toulouse-Lautrec. Frank Sinatra and Shirley MacLaine starred in the glitzy



For *Moulin Rouge*, a musical set against the backdrop of the famed Parisian cabaret, director Baz Luhrmann created a stylized representation of turn-of-the-century Paris with stage sets built in Australia and visual effects produced under the direction of Chris Godfrey. A moonlit establishing shot of Paris flows fluidly into a passage through the city that ends with the arrival of Christian (Ewan MacGregor), a young writer seeking creative inspiration. The scene, employing digital matte paintings and set extensions, was produced by Animal Logic Film.



For *Moulin Rouge*, a musical set against the backdrop of the famed Parisian cabaret, director Baz Luhrmann created a stylized representation of turn-of-the-century Paris with stage sets built in Australia and visual effects produced under the

backstage drama *Can-Can* in 1960, which was followed by the peculiar, but no less tuneful, *Le Pétomane* in 1979.

direction of Chris Godfrey. A moonlit establishing shot of Paris flows fluidly into a passage through the city that ends with the arrival of Christian (Ewan MacGregor), a young writer seeking creative inspiration. The scene, employing digital matte paintings and set extensions, was produced by Animal Logic Film.

The latest big-screen treatment, *Moulin Rouge* – from Australian filmmaker Baz Luhrmann and Twentieth Century Fox– resembles these predecessors only in its use of the club as a narrative backdrop. “*Moulin Rouge* was very much Baz’s vision,” commented production designer Catherine Martin, Luhrmann’s wife. “He was interested in finishing a trilogy of myth-based films, after *Strictly Ballroom* and *Romeo + Juliet*, set in a recognizable world that’s sufficiently removed from reality to allow certain eccentricities of storytelling, which enable you to access a very simple, but big, emotional story. *Moulin Rouge* is a culmination of this.”

Ostensibly, *Moulin Rouge* tells the simple tale of Christian (Ewan McGregor), a young writer who arrives in turn-of-the-century Paris seeking creative inspiration. Christian falls in love with Satine (Nicole Kidman), a courtesan and star at the Moulin Rouge, and struggles with the knowledge that Satine must submit to the whims of her master, Henry Zidler (Jim Broadbent), and a wealthy investor, the Duke (Richard Roxburgh), if she has any hope of becoming a real star in a real theater. Lavish and operatic, with Madonna dance numbers rubbing shoulders with Offenbach, the movie traces the fateful and impassioned romance of Christian and Satine.

For thematic guidance, Luhrmann and his co-writer, Craig Pearce, chose the legend of Orpheus– the minstrel who attempts to rescue his dead lover from the underworld– as the basis for their story. “In the Orphean myth,” Martin explained, “Orpheus has a fabulous talent– his singing– that allows him to pass through the underworld unscathed. The king of the underworld grants Orpheus his wish to bring his love back to the upper world; but with the understanding that if he looks back, she’ll be damned to remain in the underworld forever. In our story, the looking back is jealousy. When our hero falters in his love, this precipitates a series of events that brings about the eventual tragedy.”

Moulin Rouge posed a challenge that neither Luhrmann nor Martin had faced previously in their careers. Whereas *Romeo + Juliet* had been filmed largely on location, making limited use of digital technology to add stormy skies and set extensions during postproduction, Luhrmann chose to shoot virtually the entire *Moulin Rouge* on soundstages as a means of controlling the lighting and choreography. Consequently, visual effects would play a much larger role, creating all the views of the city beyond these soundstage sets.

To realize the effects assignment– ultimately more than three hundred shots– Luhrmann brought on Animal Logic Film co-founder Chris Godfrey as visual effects supervisor. Hired as an independent contractor, Godfrey would spend many months, prior to the start of shooting, laying out specific shooting, design and technical strategies for the visual effects needed to accommodate the director’s artistic vision. “Baz wanted the main focus of Paris to be the *Moulin Rouge*,” Godfrey said. “He wanted it to seem as though it was a Bangkok of the era, where the rich and powerful would come to buy the young and beautiful. It also had to have a Studio 54 feel about it– it was sex, drugs and rock and roll, with the continual thumping beat of

a party going on. The rest of Paris is nondimensional; but as you get closer to the Moulin Rouge, it becomes more exciting, more dynamic and, in a strange way, more real.”

Luhrmann’s principal mandate, however, was that the visual effects should reflect the theatricality of the production and capture the essence of the filmmakers of that period- notably the Lumières, Georges Méliès and F. W. Murnau. “The visual effects on this film were heavily design-based,” said visual effects producer Holly Radcliffe, who joined Godfrey during the preplanning stage. “That’s what makes them so unique. All of the processes we established were derived from Baz’s insistence that the effects be designed according to a theatrical, old-world painterly style he had in mind for the picture. He wanted to manipulate the medium of visual effects to create a world that didn’t look at all like a visual effect- where everything looked like it lived in this made-up, but nonetheless real world. In a way, he wanted to use computers to produce images that would go against everything computers have been set up to do.”

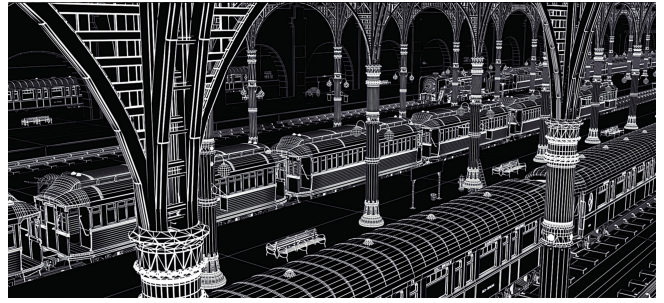
Radcliffe and Godfrey assembled a shot breakdown and put the job out for bids, eventually awarding the principal effects work to Animal Logic. Also recruited to the production- headquartered at Fox Studios Australia in Sydney- were the Mill Film motion control unit from London, and Los Angeles vendors Persistence of Vision Digital Entertainment, Asylum Visual Effects and Digital FilmWorks, with Godfrey overseeing the entire postproduction effort, as well as the bluescreen, motion control and model work. Local Sydney contractors included special effects supervisor Brian Cox- a veteran of Godfrey’s prior assignment, *The Thin Red Line*- and Tom Davies, who supplied both props and miniatures.

The approach of combining miniatures, digital and live-action elements to realize background environments would spring from early work on the film’s opening shot, which begins with a wide view of Paris, then pushes in towards a street leading to the gates of Montmartre. “Baz wanted to begin his film by traveling into footage of Paris that looked like a piece of silent film,” Catherine Martin stated. “He wanted to take the audience into that world and into the beauty of those early silent films, where the visuals did not always look perfect. He wanted the visual effects to have a handmade feel, to hark back to those olden days, rather than be seamless in terms of their digital perfection.”



The bustling Gare du Nord train station- the point of embarkation for Christian when he first arrives in Paris- was created as a 3D digital environment by Animal Logic.

From the Bazmark production offices at Fox Studios in Australia, Martin and her art department initiated the design of the opening shot by creating Photoshop collages of Paris based on period prints of the city. Using those, Chris Godfrey assembled a view of Paris, built in 2D layers, and animated a low-tech move into the image, producing what became known as ‘the postcard effect.’ “The idea was that we would first see a view of Paris, 1900, that jittered and looked aged,” Godfrey commented. “Then we would start to move past these layers that looked like



The bustling Gare du Nord train station- the point of embarkation for Christian when he first arrives in Paris- was created as a 3D digital environment by Animal Logic.

theatrical flats or a pop-up postcard- but with live-action projected on them showing hundreds of people walking along the street, passing you in a 2D plane. The 2D would then become 2½D- which is 3D squeezed in ‘z’-depth- then slowly become 3D, then models, then live-action.”

After conferring with Luhrmann, Godfrey- with Animal Logic 3D supervisor Brett Feeney and lead art director Andrew Brown- expanded on the postcard effect, designing the shot by taking an aerial map of Paris and tracing paths for the virtual camera to traverse, sketching in the 2D ‘pop-up’ buildings and devising possible transition points to 3D. Meanwhile, art director Simon Whiteley was assigned the task of creating the main city view. Whiteley flew to Paris for a week to gather photographic textures and high-angle panoramas- including a wide-angle photo-mosaic taken from atop the Eiffel Tower- then used the photographs as raw material for an elaborate digital matte painting of the city. Supervising Inferno artist Kirsty Millar next divided the painting into manageable sections, imported these into Inferno and handed them to members of her twelve-person 2D team, which also worked in Cineon, Illusion and Henry to complete the scene.

“Mark Barber comped in some live-action to populate the streets,” related Millar. “He put boats on the river, and added live atmospheric smoke and chimney smoke. Senior 3D animator Chris Cooper created the chimney smoke with a mix of 3D Studio Max and live-action smoke, which we tracked in individually to chimneys. Those one hundred frames were then taken back to 3D and broken up into 2D flats. That became our first pass, in the bottom part of the screen. The next third of the screen above that was 3D, with further layers of depth. Behind that, Grant Freckelton created a matte painting of the sky and distant Paris, including a painted river with animated sparkles to give movement to the water.” The distant view would become a signature piece of the film- a recurring image of Paris shown at various times of the day or year- that was added to a scene whenever it was felt more breadth and scope were needed.

To gild the opening vista with its silent-movie feel, Millar experimented with creating varieties of period flicker. “We went through a lot of permutations trying to achieve the correct archival look for that opening shot,” said Millar. “We were trying to decide if it should be new-old film or old-old film.” Influencing the color palette is the voice-over narration of Christian, recounting how his girlfriend has just died, as the camera weaves through streets in grungy monotone before finding the speaker’s window. As Christian then recalls his first arrival in Paris, the mood

brightens, with the camera retracing its journey in a softer, less degraded sepia tone. Millar achieved both antique film looks with a digital, but handmade approach. “We added a lot of grain, blowing out the darks, blowing out the highlights, adding just a little dirt and sparkle, with projection flicker and a bit of softening around the edges. We started off hoping that we could run this through one process, but we soon discovered that we needed further color correction. We also had a couple of designers playing with film, splashing it with coffee, adding a splice, then scanning that in to add over the top.”

In addition to such virtual city views, the film would feature many environments realized through motion control model photography. Early during preproduction, supervising art director Ian Gracie had encouraged Luhrmann to pursue the use of miniatures for window views of Paris as a means of emphasizing the theatricality of the film. These views would be seen from the interior sets spread across five stages at the Fox studios.

The main set of the Moulin Rouge stood almost fifty feet high. Complete with its façade, the impressive structure contained the stage, a dance floor, café level and an upper balcony- an entirely practical build, with no visual effects extensions- above which a giant V-shaped curtain was suspended from the ceiling, repositionable on rails. In a separate setting, a five-story elephant- a replica of a stucco oddity that occupied the real Moulin Rouge garden during the 1889 Universal Exhibition- stood as another practical element. The elephant- a steel understructure clad with styrofoam hand-carved with a chainsaw- was fashioned over a period of six months, and contained a staircase in one of its eight-foot-diameter legs. Like its historical counterpart, the staircase permitted visitors to ascend to the ‘red room’ in the belly- Satine’s boudoir in the movie- or continue to an oversize howdah on the animal’s back.

For the window views, Tom Davies and a team of eight modelmakers spent four months building replicas of the exteriors of the principal structures around the Moulin Rouge. Working from layouts of the existing interior sets, the miniature crew built Christian’s garret, the façade of the Moulin Rouge, Zidler’s apartment and the Duke’s gothic tower, which flanked the Moulin Rouge garden. To create an illusion of depth, the models were constructed in one-third, one-fifth and one-eighth scales, then backed by a painted cyclorama. “The buildings were three-sided wood or medium-density fiberboard structures,” Davies recalled, “designed so that they could be redressed and utilized in more than one position. Most of the buildings were supposed to be rendered brickwork, so we skinned them in plaster, then distressed the surface, breaking pieces away, adding texture in the form of sawdust, sand or tea leaves. Texture is one of the most important considerations when working with miniatures. What works in the distance very rarely works close up, and vice versa. What you often have to do is make something realistic for a long shot, then use a different texture and paint treatment if it’s also seen in closeup. Even when you’re working in fairly large-scale miniatures, it’s a mistake to be too precise. So we not only exaggerated textures, but we also slightly exaggerated any imperfections and irregularities in the architecture. On film, it looks more interesting.”

For areas of exposed brickwork, Davies’ team fashioned texture patterns out of timber to appropriate scales, vacuformed styrene sheets over these timber bucks, then laminated the styrene to building walls. They then put a thin layer of plaster over the textured surface, crumbling it away to reveal brickwork through the natural fissures. Although some of the

buildings had miniature slate roofing fashioned from styrene, most of the Montmartre rooftops were clad with bitumen fabric, in keeping with the impoverished living standards of the area. To prevent these rooftops from looking too flat, modelmakers used tea leaves and ground coffee to create suitable detritus.

As shooting began on the soundstage sets, the scale of the production increased dramatically, with Luhrmann asking to see an entire expanse of the city outside the windows of the interior sets. "Baz wanted twenty or thirty thousand buildings flowing off into the distance," noted Godfrey. "That's when we got into CG and the replication of models using multiple passes with motion control." Godfrey proposed expanding the use of miniatures beyond the window views, re-creating full-scale exterior sets in miniature. By tracking Luhrmann's live camera moves, a motion control camera could duplicate shots in miniature and, by multiplying buildings with repeat passes, live sets could be blended with fluid model moves beyond the physical limitations of the stage. Extras posing as Parisians could then be shot as bluescreen elements and used to populate the miniature scenes.

To accommodate the expanded model shoot, modelmakers ended up detailing the miniatures with street-level features such as shop fronts, signage, blinds and awnings. “Baz asked us to imagine the occupants living in each one of the buildings,” Davies said, “to picture what they might have on their balcony, if they’d have a broken window pane, or a pair of socks hanging on a washing line outside. We also found some interesting reference photos of Montmartre rooftops, showing broken chimney pots, where roof repairs had taken place, and litter, as if someone had a rooftop party, then left a table and some broken bottles, and dumped a chair off of their balcony. We used some little plastic chairs that were part of a Barbie collection for that, but everything else we built from scratch.”

Reviewing his shooting strategy with Luhrmann, Godfrey delineated scenes that would blend live-action with miniatures using motion control, then had storyboards drafted by artist David Russell. To further clarify the motion control model sequences, Godfrey and Radcliffe brought in David Dozoretz, founder of the previsualization company Persistence of Vision. Dozoretz selected a skeleton crew- Dan Gregoire and Euisung Lee- and flew out to Sydney, armed with three Macintosh G3 Powerbooks and a G4 desktop. “We rented monitors in Sydney because monitors from the northern hemisphere don’t work so well in the southern hemisphere, and vice versa, because of the magnetic poles,” said Dozoretz. After a tour of the sets, some still under construction, the Persistence of Vision artists set up shop in the hall across from Luhrmann’s office, where they began building a 3D model of the Moulin Rouge in Electric Image, based on production illustrations and blueprints. “Baz was very much up to his ears in main-unit shooting,” stated Radcliffe, “but somehow we had to get a plan for realizing the very complicated miniature shots penned in the script. Unfortunately, we had to start this process while main-unit shooting was at some of its most intense points, and get Baz familiar with and thinking about these effects shots- quickly.”

Within two days, the team had created a digital version of the set, with simple textures and basic representations of the performers, and was ready to start previsualizing shots with the director. “We would wheel the computers over to the sound stage to present the previzes at the end of a day’s shooting,” said Radcliffe, “then have them available on set via playback so that



The exterior of the Moulin Rouge- one of many stage settings conceived by production designer Catherine Martin- was photographed against a blue backing and combined with miniatures and digital set extensions for wide views.



Miniatures for the show were built by chief modelmaker Tom Davies and a team of eight.

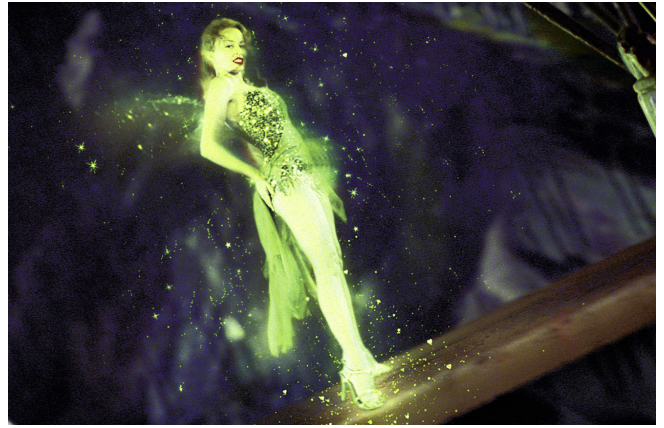
while Baz was shooting, he could also look over and see these moves playing, and think about them.” Dozoretz remained for two weeks, then departed, leaving Lee and Gregoire to continue producing animatics for another month at the rate of about one shot per day. Their original estimated shot count of eight climbed to fifteen complex and often lengthy moves, visual references for scenes that would eventually weave complex blends of elements in their final composite.

While reviewing the previzualizations, musical timing was always a crucial factor for Luhrmann in deciding the rhythm of a scene. “In a lot of cases, the visuals were working for the sound,” observed Dozoretz. “A lot of the music had been figured out, so we were timing our animation to the cues, which were often spaced far apart in unusual rhythms.” The role of music in the film also impacted the work being done by Animal Logic. “We had to have everything to music,” remarked company visual effects producer Fiona Crawford. “Even in the beginning, when we were doing low-resolution renders, Baz really could not see what he wanted until the shot was put to music. So we had to fit the 3D and 2D team with speakers before we even started, bringing audio onto every machine.”

With Persistence of Vision’s previzualizations as a guide, Godfrey strove to keep technical complexities to a minimum while shooting with the actors on set, allowing Luhrmann and director of photography Don McAlpine to set the pace and the style of shots that would be completed in miniature by motion control. “Everything was driven by the live-action,” Godfrey stated, “Baz always wanted a very interactive, malleable camera movement.” To set up the match-move pipeline, a Panascan laser survey team recorded scans of the full-scale sets, while Animal Logic 3D animator Brian Kranz took physical measurements of the miniatures. Lead 3D technical developer David Dulac built digital models of the sets in Animal Logic’s computers, while senior 3D animator Ian Brown matched live camera moves using 3D Equalizer, then extended moves within the digital model, establishing the basis for the miniature motion control shoot.

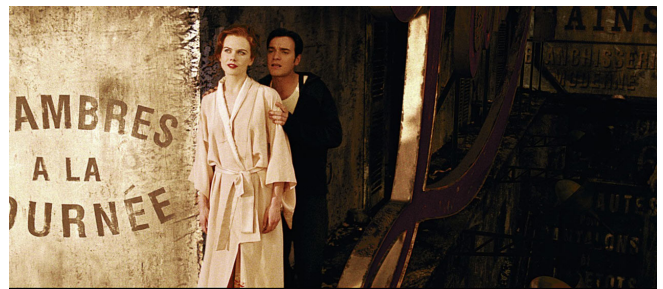
To helm the motion control, Godfrey turned to Malcolm Wooldridge at Mill Film in London, with whom he had previously collaborated on *Babe: Pig in the City*. The eight-week shoot commenced with Wooldridge’s arrival in Sydney, accompanied by a Milo motion control rig, motion control camera operator Digna Nigoumi, 3D supervisor Andy Bull and a 3D Softimage animation system. Working alongside Animal Logic on-set technical directors Charlie Armstrong, who advised on 2D compositing issues, and David Dulac, who performed set surveys and shot reference photos for 3D, Wooldridge and Godfrey reviewed their plan of attack for the complex shots. Godfrey would provide Wooldridge with Animal Logic’s Softimage animation files derived from live-action moves; Bull would take the moves into the Mill Film motion control rig, via their proprietary software interface, Milo-Softimage; then Nigoumi would program the miniature set moves, tweaking and re-timing as Luhrmann required. Animal Logic would then re-match final moves where necessary and assemble the multiple passes.

"It was quite a procedure," related Wooldridge. "Don McAlpine was very accommodating, lighting for his beauty passes, then helping us with anything else that was required for the motion control. We also got involved with the art department early on, blocking out wherever we knew we would have to cut apart the set to allow passage for our camera. Sometimes we could not shoot a scene as a one shot; so we would shoot as much as we could, they would dress the next part of the set in, then we would continue shooting."



Embracing the bohemian lifestyle of the city's resident artists, Christian is introduced to the pleasures of absinthe, personified in the form of a green fairy who springs to life from a label on a bottle of the mind-altering liqueur.

The rotating blades of the Moulin Rouge windmill played a key role in planning motion control setups. Modelmakers installed a servo motor into the windmill, allowing Wooldridge and his crew to synchronize the rotation of the blades with the movement of the Milo rig. By timing the camera's approach to the moment that the windmill blade obscured the lens, a seamless wipe-cut could be achieved, so the set beyond could be redressed, allowing a transition to a change of scene. "The rotation of the blades was also very important for Baz in setting the pace of the move," Wooldridge added, "so he was very particular about programming the rotation speed."



In song, Christian professes his love to Satine (Nicole Kidman), a performer at the Moulin Rouge. In the course of the scene, the camera journeys from the ledge outside the poet's garret through the streets of Paris to a park in which the couple is picnicking. Animal Logic blended live-action with miniatures, matte paintings and digital set extensions to convey the desired effect.

Wooldridge strove to maintain maximum depth of field throughout the miniature shoot, image sharpness being a prime factor in establishing the illusion of scale. "Don was giving us a good f-stop," Wooldridge commented, "but we were then undercranking, with the aperture closed down as far as we could go, to get as much depth of field as possible so that everything would be sharp. We were using Kodak SFX 200T stock in Super 35mm format, shooting close-focus with spherical wide-angle Primo lenses. Frame rates would vary from half a frame to two frames per second, depending on the shot. Some passes took as long as thirty



In song, Christian professes his love to Satine (Nicole Kidman), a performer at the Moulin Rouge. In the course of the scene, the camera journeys from the ledge outside the poet's garret through the streets of Paris to a park in which the couple is picnicking. Animal Logic blended live-

minutes; others took just a couple of minutes. Video comps were completed for Baz to review before any shooting was carried out. Often they were overlaid with music so he could get the feel of pacing for the shots.” After establishing the look of the shoot in the first two weeks, McAlpine took his leave and Steve Dobson took over as miniature director of photography. With oversight from

Godfrey, the Mill Film crew completed fourteen motion control setups in eight weeks. An additional six weeks of model work would follow, with Godfrey supervising hand-held camera moves, tracking shots, crane shots and wild repeat passes that were incorporated into the film.

The final miniature assignment came late in production. While assembling the first reel of his movie, Luhrmann realized that he needed an introductory sequence in which Christian reflects on his experiences at the Moulin Rouge and the camera sees his mind’s-eye view, drifting through the empty main hall. Unfortunately, by this time in production, the main hall set had already been destroyed. The only practical solution was to re-create it in miniature. When the initial cost projection precluded building the set in its full glory, Luhrmann rewrote the scene as a journey through the derelict hall, which made the project feasible, given the need for less detail. Tom Davies- whose crew had been cut to three by this point- had to recruit new members, then set to work creating a twenty-by-thirteen-foot, fifth-scale replica of the hall. Pushing through the front door, the camera prowls piles of stacked-up chairs, tables dressed with absinthe bottles, glasses, ashtrays, ornate mirrors, cobwebbed sconces and a seventy-two-armed chandelier under canvas, lowered from the ceiling. The move comes to a rest on a tattered curtain, which transitions- via a greenscreen composite- to Zidler making his appearance on the full-scale set.

The arrival of the first motion control plates at Animal Logic brought production into full swing as the company focused its 3D efforts on building complex portions of Paris seen in wider establishing views. The modeling initiative began on a small scale with a scene featured later in the film. “We had a balcony scene with Christian and Satine singing ‘Come What May,’” said Brett Feeney. “The camera pulled out revealing Montmartre as a slummy area with buildings all around, but it didn’t go as far out as the introduction shot. We knew our parameters here were basically all 3D, leading off into a matte painting in the distance, so we used this as a place to start.” Using high-resolution transparencies from the miniature shoot and further closeup studies of the miniatures photographed at Animal Logic, five of Feeney’s twelve-person 3D crew began modeling closeup structures. “We relied heavily on a lot of the functions in RenderMan. Much of the geometry was extremely simple, so we applied some complex displacement maps to give the impression that a lot was going on. Most of the buildings were six- or eight-sided objects. We mapped them out and detailed them, but it was a beast getting those displacement maps to work.”

Working under R&D director Guy Griffiths, head programmer Chris Bone implemented a proprietary technique to assist in the modeling process, bringing Softimage into RenderMan. Known as ‘SoftMan,’ the plug-in allowed both Photorealistic RenderMan and Blue Moon

action with miniatures, matte paintings and digital set extensions to convey the desired effect. In song, Christian professes his love to Satine (Nicole Kidman), a performer at the Moulin Rouge. In the course of the scene, the camera journeys from the ledge outside the poet’s garret through the streets of Paris to a park in which the couple is picnicking. Animal Logic blended live-action with miniatures, matte paintings and digital set extensions to convey the desired effect.

Rendering Tools shareware to be used from within the Softimage animation program. In all, Animal Logic built twenty high-resolution 3D buildings, designed to allow placement to camera from a variety of angles. These were lit with radiosity, a global-illumination light simulation technique, reducing the need for key-light, highlight and bounce-light passes in 3D.

Lower-resolution models were placed beyond this, with procedurally-built models in the middle background. Chris Bone and technical team leader Justen Marshall also built a plug-in in Softimage called 'Get Primitive Paris' that enabled housing to be reproduced from a scan of Andrew Brown's aerial map of Paris. "We could pick a section of the map in our computers," related Feeney, "and generate as many houses as we wanted, altering their height, adjusting their depth, applying whichever texture map we wanted. There was also a facility for generating roof junk- like chimneys, or lofts- to break up the horizon. Depending on the different styles of texture maps we used, we could pick our area, pick which style of house we wanted to put into that area, and then say, 'Okay, plug-in, do your nastiest!'" The procedural city-builder allowed Feeney to generate vast areas of housing five or six times a day, saving untold labor and allowing multiple permutations. "If we ran a combination of settings and wanted to make a slight change, we could save what we had, program the alteration, then generate the buildings much as they were before, but with that alteration. We could pick a suburb, run it with the plug-in, then make it a little more bourgeois by using different texture maps. We were building Paris by numbers."



Asylum Visual Effects supplied the dazzle for a musical number in which Moulin Rouge impresario Zidler (Jim Broadbent) takes flight over the cabaret courtyard. Bluescreened extras were composited into motion control footage of a miniature courtyard set, which then served as a plate for the foreground wire-flown actor.

Feeney's team then applied its 3D cityscapes to the final version of the film's introductory shot, which by this time had grown to include a three-mile move across the city, with the camera starting wide, then pushing in towards a street that leads to the gates of Montmartre, flying through the streets and up through Christian's garret window. In a subsequent shot that echoes the opening, but travels back in time to Christian's first arrival in Paris as a young man, the camera slingshots back from the garret into a 3D version of the Gare du Nord train station. Following the writer as he disembarks and approaches the gates of Montmartre, the camera once again flies through the streets of Paris to the garret. Animal Logic and Chris Godfrey designed the four-minute sequence as a detailed progression through the postcard landscape, reflecting Christian's naiveté and excitement, squashing and offsetting the perspective of the 3D buildings before entering full 3D.

Animators Aidan Sarsfield, Chris Cooper and Craig Brown produced digital models of the train station exterior and interior, drawn largely from photo reference and lit, again, with radiosity. "That all helped the hyperreal feel," said Feeney, "coming from the 2D flats which, although they are obviously not real, used similar 3D textures. We modeled the interior shot in high detail to accommodate a camera move descending from the rafters to a railway carriage, from which Christian disembarks. The external version of the station was complete with trains in the

external shunting yards, and trains pulling into the platforms inside, but it was a much simpler piece of geometry that made extensive use of displacement mapping. We also generated fairly detailed 3D background models of the Eiffel Tower and Sacre Coeur, but these were not featured at high resolution.”

Christian’s entry into Montmartre combined bluescreen footage of Ewan McGregor, re-timed to match it to 3D, then composited with a similarly retro, idealized feel. “We filmed some bluescreen characters, put them into the matte painting and treated it as a sequence of dissolves,” said Andrew Brown. “You see Christian walking into the scene, but the idea was that it look like back-projection or an effect that could have been created in-camera at the time.”

Making the acquaintance of his new neighbors, Christian encounters Henri de Toulouse-Lautrec- whose height, at four feet eleven inches, is the result of a genetic bone condition. When John Leguizamo- height, five feet eight- was cast as the famously diminutive artist, the studio flagged the character as a big visual effects concern. “In my first meeting with Fox, somebody suggested CG leg replacement for Toulouse,” recalled Chris Godfrey. “I ran away from that idea like the plague. Baz wanted interaction. He wanted a tactile feeling between the actors. If we had pulled John out of every shot to put him in front of a bluescreen, that would have been a huge problem.”

Two strategies were ultimately incorporated into the final effect. For interactive scenes, Leguizamo knelt into a pair of prosthetic legs, made by Studio Kite, that brought his height down by eight inches. “John’s legs came out of the back,” Godfrey commented. “We had him wear black stockings so we could paint out his real legs, but we did this less than a dozen times in the whole show. The real trick was that John gave such a great performance, his face sold the effect.” For more ambulatory scenes, Godfrey shot tests of Leguizamo against bluescreen, with the camera positioned eight inches above the actor’s head to create a downward-looking perspective, then morphed Leguizamo’s legs up into his body eight inches. By compositing Leguizamo into a background plate with his feet placed on the ground, other performers towered over him.

Taken into Toulouse-Lautrec’s confidence, Christian is next introduced to the Green Fairy, a fantasy character that springs from the label of an absinthe bottle. The character began life at Animal Logic as hand-drawn animation supervised by animation director Don Ezard, and was originally slated to take on a demonic nature. The final concept, designed by art director Belinda Bennetts, featured a more benign live-action performance by singer Kylie Minogue, filmed as a wire-flown bluescreen element, composited with fluttering animated wings, a sparkling aura and green interactive light. “We looked at Victorian fairy paintings as reference,” observed Andrew Brown, “and we gave her a bit of a Méliès treatment, adding projection flicker so she didn’t look too perfect.”

The fairy leads the revelers towards the Moulin Rouge via a swirling vortex- a combination of 3D, miniature and bluescreen elements. “We shot the windmill with motion control, with and without the windmill blades,” explained Godfrey. “Then we did versions with green light, using Promist filters to give it a hazy nighttime look and take the edge off the models- we generally used a black Promist for day, and a white Promist for night. We then shot the actors against

bluescreen, kicking and screaming, on an inclined plate, and comped them in as polygons, whizzing around inside our 3D vortex. The overriding style was to keep it simple, to match the rest of the action.”

As Animal Logic’s workload mounted, Godfrey and Radcliffe hired Asylum Visual Effects to take on some fifty shots- including those featuring digital crowd replication. One of the most challenging of the crowd scenes occurs shortly after Christian’s arrival at the Moulin Rouge, during a dance number- known as ‘Zidler’s rap’- in which Zidler ascends the windmill during a rainstorm and takes flight, plummeting across the garden, skimming the crowd beneath him, then back-flipping into the main hall. To fill the garden with some six hundred nightclub patrons reacting to the flight, Godfrey persuaded two grips to improvise a jig against a bluescreen. He then created a video composite of them using the Persistence of Vision previz, offsetting the dancers’ timings and tracking them in as 2D polygons. When the low-tech test held up in the context of the shot, Godfrey filmed groups of costumed extras against bluescreen, getting a generic perspective on them by utilizing a 50mm spherical lens, mounted above head height. He then shot Jim Broadbent against bluescreen, tumbling on a wire rig, and filmed rainfall passes in the studio parking lot. Mill Film set up a nine-pass motion control move on the garden miniature, timed to the previz, starting high up in the windmill and descending through the moving blades. Asylum assembled the elements.

“The difficulty of these shots,” stated Asylum Visual Effects supervisor Nathan McGuinness, “was determining how far we could go tracking a locked-off shot- which wasn’t matched with motion control- into a dynamic camera move.” Asylum had originally intended to track the entire swooping camera move in Inferno, but the distance and the speed at which the camera was traveling made this prohibitively time-consuming. “We eventually matched the camera move in 3D. Then my lead Inferno artist, Marty Taylor, matted and created foreground mattes for the crowd. 3D artist Yuichiro Yamashita placed them in space and rendered them with motion blur in Maya, matched to the blur of the background plate. Marty performed the composite. There were hundreds of layers with luminance mattes all over the place, but this shot taught us how far we could go in Inferno, without resorting to 3D.”

A less radical camera move- a gentle push-in past the windmill peering down into the garden- featured throngs of diners, strolling restaurateurs and couples carousing on balconies, and was done entirely in 2D. By creatively sampling the array of bluescreen elements, cutting, pasting and flipping characters, and tracking them into the shot, Asylum Inferno artists were able to maintain the illusion of three-dimensional perspective throughout the tracking camera move. “Some of our extras down in the background of the shot were filmed looking up,” remarked Marty Taylor. “I ended up tweaking them a little, adjusting their cubic perspective, so they were bent the other way, as if the camera was looking down on them. With a little ambient light, they fit right into their environment.”

A number of bridging shots- some simple, some complex- were executed by Asylum to transition from one scene to another. One especially inventive hookup featured a move from Satine in her boudoir to an establishing view of Christian’s garret. Asylum took a locked-off shot of the red room, composited it into the elephant miniature, zoomed the camera back, then flipped the scene back over itself 180 degrees. Revealing the garret miniature, upside down,

Asylum then performed a barrel roll, righting the image before the camera commenced its move towards an interior scene tracked into the window. “The effects editor, Shannon Leigh Olds, gave us a good representation of the scene as a rough video precomp,” said Nathan McGuinness. “We took the elements from the interior set to the pulling out of the elephant, then added the starry sky above to bridge the apex of the move as the camera tilts back. Marty Taylor joined it all together.”

Asylum also took on a fantasy sequence, conceived by Andrew Brown and Grant Freckelton at Animal Logic, in which Christian and Satine fall in love to the tune of Elton John’s “Your Song.” The scene begins with the couple leaping from Satine’s red room inside the elephant, then waltzing up into the night sky high above the Moulin Rouge, where they are serenaded by a singing Méliès-style man-in-the-moon. Live-action plates delivered to Asylum featured Kidman and McGregor filmed in front of a vivid-blue sky backdrop on sets covered by dry ice, giving the impression the couple was



A fantasy sequence in which Christian and Satine waltz through night skies over the Moulin Rouge was assembled from live and digital elements by Asylum.

dancing on a bed of clouds. Asylum essentially added the environment surrounding the characters, color grading the sky, inserting rolling clouds and a cityscape, and adding 3D pixie-dust animation beneath the actors’ feet in the shape of a bridge that they traverse. Further digital layering included the compositing of a prosthetic singing moon element, photographed in Sydney and tracked at Animal Logic. “Laurent Ben-Mimoun spent a long time building matte paintings of a beautiful, photoreal Paris skyline,” explained McGuinness. “We added some very deep 3D particle animation clouds, which Yuichiro Yamashita built with some nice parallax moves of the 3D cameras in z-space, and which we layered to make it look like it was a cutout matte painting. So we started out by making it look real, then we made it more surreal.” As the song progresses, Christian grabs hold of a stray floating umbrella and takes flight around the Eiffel Tower. Asylum took a stock 2D element of the tower, rotoscoped it from its original background and matted it into the scene with McGregor in 2D.

Following the lovers’ first, magical kiss in a subsequent scene, Toulouse-Lautrec appears seated on his balcony, singing. The shot of the artist, his short legs hanging in full view, posed a problem solved on set by physical effects supervisor Brian Cox. “We made a couple of fiberglass fake legs with simple push-pull cables for John to wear,” said Cox. “We cut a slot into the styrene parapet; John knelt just below, with his fake legs hanging over, while we operated the cables from behind. It was a last-minute thing, but it gave his legs a bit of movement as he was singing.”

Cox was on call throughout the twenty-week shoot, providing a diverse array of mechanical gags. “It was really the old wire, tape and rubber band stuff,” noted Cox. “We did a lot of theatrical tricks, lifting Nicole up through the stage, creating petal drops, releasing paper hearts through air movers to make them flutter down.” Environmental effects included dry-ice fog for Christian and Satine’s dance across the sky, and an interior rain gag from an overhead

grid system for Zidler's rap at the façade of the Moulin Rouge. Pyrotechnic gags included a fire-breather act on stage beside principal performers- a 2D composite of flames shot against black, keyed, warped and color corrected with animated interactive light supplied by Animal Logic. Cox also provided orange stage flares designed to blow out the frame long enough to allow magical match-cuts between scenes in a third-act stage performance.

The most complex physical effect involved the launching of top hats from eighty-nine dancers' heads during the big finale. "Baz always wanted to get whatever he could in-camera," remarked Cox, "and he wanted all of these hats to kick off simultaneously, to shoot into the air about twenty feet and come back down on cue." After consulting with choreographer John O'Connor, Cox had his team construct an aluminum scaffold grid, approximately thirty-three feet square, with eighty-nine miniature pulleys radiating in a circle from a center axis. Each hat was loaded with a spring inside the crown, fastened to a thin wire that extended out through the top. The night before the shoot, O'Connor indicated dancer placement in a circle on stage. The physical effects team aligned the pulley rig overhead, fed wires from the hats up over the pulleys to another grid containing larger pulleys, and affixed counterweights. When the dancers came in the next morning, the hats were all spread out on the ground. "It worked out pretty well," observed Cox. "When the girls dancing the cancan kicked up their heels, we released the counterweights on cue and all of their hats flew off. Timing was tricky, because some of the lines had a bit of slack in them and some didn't; but the ones that had slack in them really 'poinged' and snapped up in the air. We had them come off and on about eight times. We never got around to dropping them back down, but Baz was happy."

The final visual effects vendor to join the production was Digital FilmWorks, which created the effect of a storm gathering in the skies above Paris, featured in a scene following Satine's tearful breakup with Christian. Digital FilmWorks supervisor Paul Bolger oversaw production of the effect, which was generated to match black-and-white footage from an old movie, originally used in the cut. In keeping with the theatrical style of the sequence, Bolger's team created a multiplane-style series of animated cloud plates, layered into the scene.



Consumed by jealousy after losing Satine to the Duke, Christian is compelled to return to the Moulin Rouge to see his lover one last time. To emphasize Christian's dementia, the camera rushes through the Montmartre street in a dramatic tracking shot, crashing in through the nightclub doors. Godfrey filmed the scene as a six-layer repeat pass on the miniature Moulin Rouge exterior- at three frames per second as a wild move, without motion control. 2D stretched and morphed the move, tracking the shot into a live hand-held shot entering the full-size interior set.

The film's tragic finale plays out on the stage of the Moulin Rouge as a three-act musical extravaganza- Zidler's 'Spectacular Spectacular'- staged by Satine and company in an attempt to win financing and save the Moulin Rouge. When the curtain falls, Christian sees Satine collapse backstage. Depleted by exertion and racked by consumption, Satine expires in

Christian's arms. In one unblinking take, the camera rises from the stage, travels out onto the roof, tracks across the garden, through a fall of snow, passes through the windmill blades, transitions seasonally to springtime and finally comes to rest with Christian writing in his garret.

Luhrmann shot the initial rise from the stage as a wild camera move, extended as an Electric Image animatic by Persistence of Vision. After Animal Logic tracked and matched the live-action footage, Mill Film replicated the move with their Milo rig. Kirsty Millar combined both elements with a glimpse of the audience applauding beyond the curtain. To capture the view of the audience, Godfrey filmed separate plates of two hundred audience members positioned in six different seating areas. Animal Logic assembled the results and subtly multiplied the female demographic, cutting and pasting individual women when a male bias became apparent in the composite.

The scene also incorporated a bluescreen element of two Moulin Rouge stagehands viewing the action from above. Animal Logic animator Howard Fuller then continued the move in 3D through CG rafters, which took the shot out through a skylight to the roof. Mill Film picked up with a motion control element, a thirty-six-layer pass across the garden miniature in snow, shot over the course of six days. Tom Davies' crew dressed the miniature with salt, standing in as snow for the beauty pass, then draped the set in black for multiple takes of a live-action snowfall of detergent. As a postproduction addition, Godfrey photographed a high-angle shot of the Duke, staggering from the main hall. A 2D team composited this footage into the garden, adding snowy footprints.

Passing through the windmill blades, the shot then wipes to a non-motion-control move, photographed with a brighter lighting setup for spring, pushing in to the window of Christian's garret. With traffic tracked into the street and activity composited into windows, the scene was match-moved to include a view of Christian inside, seated at his typewriter. A billowing curtain flapping into frame facilitated a wipe to a closer view, photographed wild, with the camera pitched 90 degrees on its side to allow for vertical repositioning.



In the style of a vintage black-and-white film, Digital FilmWorks created brooding images of a gathering storm for a scene following an emotional breakup of the young lovers.

The three-thousand-frame sequence was in production at Animal Logic for nine months. Supervising Cineon compositor Charlie Armstrong initiated the postproduction process. As soon as shooting was complete, Kirsty Millar roughed out a low-rez composite in a week to ensure that timings worked with the music track, before the sets were struck. Senior Inferno artist David Morley then saw the shot through to completion.

Eccentric, flamboyant and unique, Moulin Rouge managed to harness modern visual effects technology in support of a distinctly stylized, retro vision, pushing its effects artisans to apply their craft in a very different way. "In Baz's adaptation of Romeo + Juliet," remarked Holly Radcliffe, "Shakespeare meets the modern day. In Moulin Rouge, the reverse is true, in a way-

modern technology and effects meet with nineteenth-century Paris. Accomplishing that required a bit of a quantum leap, but Baz pushed us to take that leap with many of the shots. In the end, you have this combination of modern effects combined with old techniques and painterly images that evokes a certain feeling or time, just as you have this story set at the turn of the century played out to music that spans a hundred years into the future.”

Ultimately, the mission for Chris Godfrey was to rein in elements spawned by the creative process. “It was fantastic to have such an open brief,” said Godfrey, “and I was able to have so much input while working for Baz, who continually came up with new concepts and wanted to try new things. Of course, we were on a limited budget, so what I had to do was optimize those restrictions. To do that, we had to sit within the concept, think the way Baz thinks, then come up with a solution that fit the flavor of the film. There’s a beat and a tempo, with criteria that are sometimes larger than just making a transparent effect. You can always buy your way out of a visual effect. It’s much more of a challenge to design your way out.”

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FLESH FOR FANTASY

ARTICLE BY JODY DUNCAN



In the early eighties, as a young man in Japan, Hironobu Sakaguchi chose a less-traveled road, dropping out of college to develop computer games for a fledgling company called Denyusha—which would change its name to Square in 1986. After four years in the business, and little success, Sakaguchi decided to make a final go of it with one more game design— if that one failed as well, he would give up his dream and return to college. That last game— titled, appropriately, “Final Fantasy” – was released in 1987 and became one of the most successful interactive role-playing games ever to hit the market. “Final Fantasy” and its sequels— its ninth title was released in November 2000— went on to sell more than 31 million copies worldwide, and Sakaguchi climbed the ranks from software developer to chairman and CEO of Square USA, which handles the company’s U.S. operations.

But his rise in the interactive game industry and the sales success of “Final Fantasy” were merely the first steps toward Sakaguchi’s ultimate goal. “My big ambition,” explained Sakaguchi, “was to build a top-of-the-line production studio where I could create a fully CG film.”

More specifically, Sakaguchi had his sights set on creating a computer animated film that would feature photorealistic human characters. To many, it seemed like a pipe dream. “Four years ago,” producer Jun Aida remarked, “when we tried to explain to people what we wanted to do, most of them just rolled their eyes and said, ‘Hey— good luck.’ It was understandable. We’d had tremendous success in the interactive game business; but to do a feature-length picture with photoreal CGI characters, produced by a totally unknown, inexperienced studio and directed by a first-time feature film director? It seemed impossible to a lot of people.” Despite such skepticism, Square managed to interest Columbia Pictures in distributing the full-length, all computer animated feature— although the production studio and film would be funded entirely by Square, allowing the company to retain full ownership of both. It was an enviably independent situation for the upstart studio and filmmakers, rivaling the autonomy enjoyed by George Lucas and his Lucasfilm.

Although it would share the name of its game predecessors- each of which featured new characters and a new setting- Final Fantasy: The Spirits Within would be yet another entirely new story populated with a cast of debuting characters. The film would also be set- for the first time in the history of the franchise- on the planet earth. "I wanted to create a story and a world where the human spirit is scientifically explained," Sakaguchi stated. "In order to make that concept more believable to the audience, I decided to set it on earth. That would be a more realistic setting than a fantasy world; and it would make the concept more realistic, as well."

The final movie runs 94 minutes and is set in the year 2065. A meteor has crashed on the planet, releasing alien creatures that roam the earth, extinguishing all life. Human survivors have retreated to barrier cities built to protect them from the marauding invaders. Among those attempting to defeat the alien predators and save the planet are Dr. Aki Ross (voiced by Ming-Na), a brilliant scientist, and a military squadron led by Captain Gray Edwards (Alec Baldwin). Their quest is impeded by General Hein (James Woods), who proposes destroying the meteor with a massive space cannon as a means of defeating the alien invaders. In the surreal terrain of her nightly dreams, Aki discovers the source of the alien phantoms and, in the process, unlocks secrets of the human spirit.

Sakaguchi conceived the essential elements of that storyline, then refined and fleshed out the narrative with screenwriters Al Reinert, Jeff Vintar and Jack Fletcher. "The entire story was generally in my head," said Sakaguchi, "and I had ideas about what kinds of scenes I wanted and how I wanted the story to evolve. However, I developed the details with the screenwriters. I had to rely on the screenwriters a lot for the dialogue, as well, which was very important."

Although, technically, Final Fantasy was four years in the making, the first year and a half of that schedule was spent in building the studio. As a site for the studio, Sakaguchi and producers Aida and Christopher Lee chose the unlikely locale of Honolulu, Oahu. "Hawaii was a very good location for a lot of reasons," observed Aida. "We knew that there were a lot of talented CG artists in Japan and other parts of Asia, as well as in the Hollywood community. Hawaii was midway between those two spots. Also, the environment in Hawaii is very creative; and it is, generally, a very good place to live. We don't have big-city problems here- no traffic or crime. It is a good place to raise children. And when you leave work, you can go surfing and swimming." Despite these advantages, the isolation of the location made the studio's recruiting efforts difficult. "Four years ago, we were nobody, and we were asking people to leave the mainland and move to Hawaii- so we had to do a lot of convincing. People were unsure about Hawaii. They'd ask, 'Do they have electricity there?' So it was difficult. On the other hand, once people agreed to come on, it made for a lot of camaraderie among the artists- because we had all left something behind. We had all said goodbye to friends and relatives to do this; and that made for a very strong bond."

In its embryonic stages, the studio occupied two floors of a Honolulu high-rise, and employed seventy people; four years later, the studio would occupy five floors of the building, and employ two hundred people. An important hire was animation supervisor Andy Jones. "Andy was just about ready to start work on Stuart Little at the time," recalled Sakaguchi; "but he was really

interested in doing more grownup animation- so we enticed him with that. 'Do you want to animate a mouse or a real human being?' He chose the human being."

Jones' background included animating the CG characters in the sinking of the Titanic sequence while at Digital Domain, and supervising animation for Godzilla at Centropolis Effects. A call from a friend and colleague who had already been hired for Final Fantasy prompted Jones to check out the new project. "It was definitely something I was interested in," stated Jones. "The nature of what they were trying to do was really pushing the envelope of computer graphics. So it was very interesting to me- even though I thought they were a bit crazy. It seemed like an impossible thing to do, given the tool set that we had at the time and where the technology was. I knew we'd need to create a lot of proprietary stuff to make it happen, and I knew it would be extremely difficult."

During much of the studio's gearing-up period, a research and development staff pressed forward to develop the hardware and software necessary for producing photorealistic human characters with computer graphics. But, while strides were made, there remained doubts as to the feasibility of the project. "Long after we started production," noted Sakaguchi, "there were still many times when I thought, 'This can't be done.'"

With the studio up and running and a full staff on hand, official production on Final Fantasy began in mid-1999. The process commenced with staging director Tani Kunitake, who created storyboards for the entire film with his team of sixteen storyboard artists, working with Sakaguchi to nail down the look of each and every shot. "Tani has a very traditional film background," related production supervisor Cameron Stevning. "He created storyboards just as he would for a live-action production, as if all the sets would actually have to be built. As much as possible, we tried to adhere to the lessons that people in live-action photography have learned." Once the storyboards were approved, they were put into a story reel format. "We actually took the boards into the Avid and edited them together, just to get a little better sense of the timing. It was basically an analog animatic. Then, after that timing had been established, those boards would be used as reference for the layout department."

In layout, the 2D storyboards were transformed into low-rez 3D images- produced in Maya- which better illustrated camera angles, timings and the basic blocking of each scene. "The layout department," said Stevning, "would use very rough block models and rough 3D geometry to make the action of the storyboards look more like what it would ultimately look like in a 3D environment."

As the entire narrative was being blocked out in storyboards and 3D layout, a team of character artists was designing and modeling all of the film's characters. Initial character sketches evolved or were thrown out altogether as the script



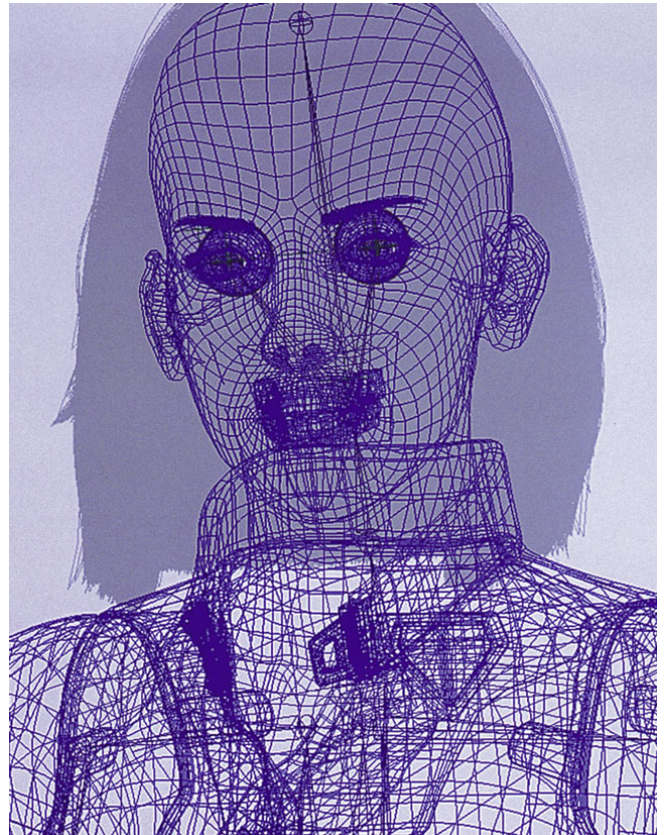
With Final Fantasy, first-time director Hironobu Sakaguchi delves into the mythology of his wildly successful computer game to present the story of a resistance force of soldiers and scientists trying

developed and storyline changes occurred.

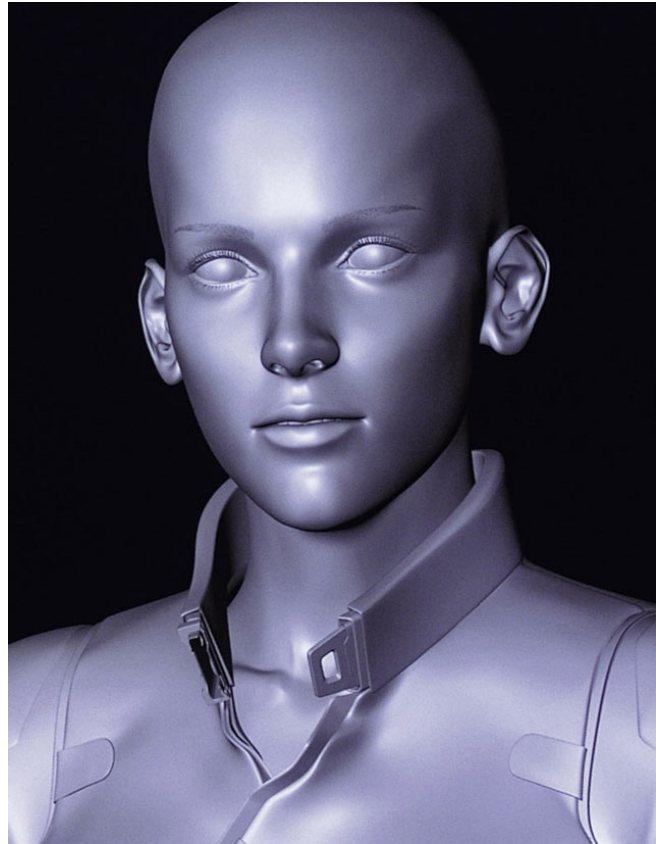
Designs changed, too, as the personalities of the various characters emerged and crystallized. “The designs always came out of the personalities,” said lead character artist Steve Giesler who was instrumental in conceiving the look of all the characters. “Stronger people were designed with a strong brow or chin; evil characters might have an arched brow. The most important part of the design process was matching the characters to their personalities so that the audience would know what kind of person this was, just by looking at him or her.”

Beyond the physicality suggested by personality, the designers were guided by Sakaguchi’s visions of the characters. “The director had a vision for the main characters,” said Giesler, “and we always tried to realize that. But when you start putting different qualities together in a 3D model, you find you can’t just throw all these random elements onto a face and expect them to come out balanced and aesthetically pleasing. So a lot of elements changed as we tried to attain that balance. We also had to balance a certain level of realism with a stylized look.”

to stop the annihilation of earth’s last surviving humans by a race of alien invaders. Among those fighting to save the battle-ravaged planet in this wholly computer animated feature are Captain Gray Edwards and Dr. Aki Ross.



It was Sakaguchi’s intent to break new ground in the creation of photorealistic CG humans. To this end, four years were spent building a studio in Hawaii, staffing it with artists from around the world, and producing a film funded entirely by proceeds from the franchise computer game.



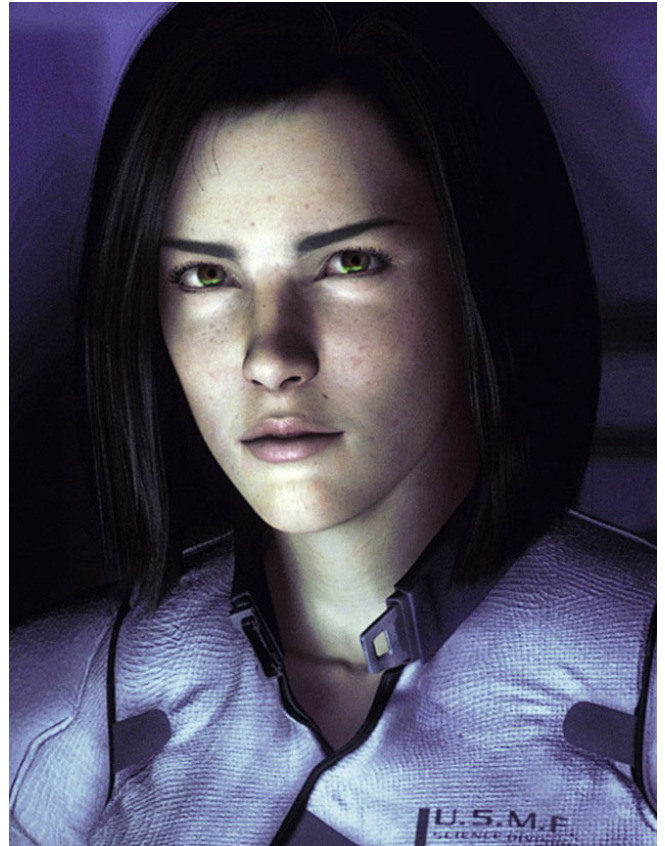
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In fact, walking the line between photorealism and an artful representation of the human characters had been one of Andy Jones' primary concerns. "I think my biggest fear when I first came to work on this show was that we would try too hard to make the characters look real," Jones commented. "I'd seen a lot of people trying to do CG humans; and it seemed the closer they got to real, the scarier they looked. I felt that we had to somehow avoid that, by creating a stylized realism that people would enjoy watching. So even though it would look close to real, it wouldn't be disturbing to watch. And I think we did that. We made the characters as subtle and realistic as possible, but with a very hand-done, artistic approach."

To create the 3D models, Giesler and his team sculpted in Maya- a tedious process that involved moving points around to create the basic shape. The result was a wire-frame form. Modeling details, such as wrinkles, were applied with a 3D paint program; however, most of the textures were painted in 2D, on a surface that resembled the peel of an orange laid out flat. That painting would then be wrapped around the 3D model. "We started with the character of Aki," commented Giesler, "and we found that most of the characters could share that base detail painting. That gave us a realistic looking start, and then we would keep adding more and more detail." The Aki model actually required the least amount of detail, since her beautiful young skin was quite smooth and perfect. "With Aki, we had to be very selective about what we did to her. 'Okay, I can put one pimple on her- where should I put it?' I did try to add some imperfections to her so she wouldn't be too smooth; but they are so subtle, you don't see them in a lot of shots."

In contrast, Aki's mentor, Dr. Sid (Donald Sutherland) required much more detail in his texture painting. "He was bearded and older," Giesler noted, "so his paint job had to have all of those details. For the most part, we didn't have the luxury of tweaking the textures for every shot; so the closeup amount of detail and the faraway amount of detail were the same. That meant that if we made it look really good for the faraway shots, it would be too much detail for the closeups. So we had to find a balance for all the characters in that respect."

The first look developed for Aki had the character in longer hair and much heavier makeup than she would sport in the final film; and the heroine went through many more looks and stages before Sakaguchi was satisfied with her appearance. Even when the look of the character was locked, however, modeling refinements continued. "There were always tweaks and fixes to be



It was Sakaguchi's intent to break new ground in the creation of photorealistic CG humans. To this end, four years were spent building a studio in Hawaii, staffing it with artists from around the world, and producing a film funded entirely by proceeds from the franchise computer game.

done on the models,” noted lead Aki animator Roy Sato. “There’d be a need for revisions on her hair or the way her eyes blinked- things that we would discover as we were animating her. We might find a weird crease forming in the corner of her mouth, for example, and the modelers would have to fix that. A lot of things we just didn’t see until we were actually doing the shots.”

Tools were developed to model and animate Aki’s chin-length hair- a chore so time-consuming and labor-intensive, the filmmakers decided that every other character in the film would have short-cropped hair. “Because there were so many hairs to deal with,” explained character artist Francisco Cortina, “we had to find a way to render Aki’s hair without its taking forever- to create an impression of hair without killing ourselves in rendering. We also had to make it so that we could style it easily, without pulling our own hair out, so to speak. So we developed tools where we could control the flow of the hair. We could modify that flow on a scalp- a sort of plate that did not get rendered. The plate would tell the hair to grow out of it in a certain way; and then we would apply the shader, which determined the coloration and the texture and whatnot. So we ended up having a lot of control over how it flowed, what it did, how it bunched up, et cetera.” Functions in the custom shader would automatically make the hair take on a different sheen in different lighting conditions.

After the head model was delivered by Giesler and Cortina, character supervisor Taiji Okusawa fashioned the character’s body, which included an internal skeletal structure and musculature. “We came up with very anatomically correct body structures,” related character technical director Kevin Ochs. “On Gray, for example, you can see the muscle structures imprinted inside the body; so when he bends, his abs crunch, just like a real person’s. When he moves his arms, you get flexing. It was all done with internal software, added to our base package of Maya.”

Animation of the models started with the 3D layout being handed over to a motion capture team, which would attempt to duplicate the action in the animatic with live actors hired both locally and in Los Angeles. The actors performed on a motion capture stage, set up at the Hawaii Film Studio production facility- a state-owned studio that had housed the Magnum P.I. and Baywatch Hawaii television productions. Motion capture line producer Remington Scott was hired to oversee the process, which went on for eighteen months.

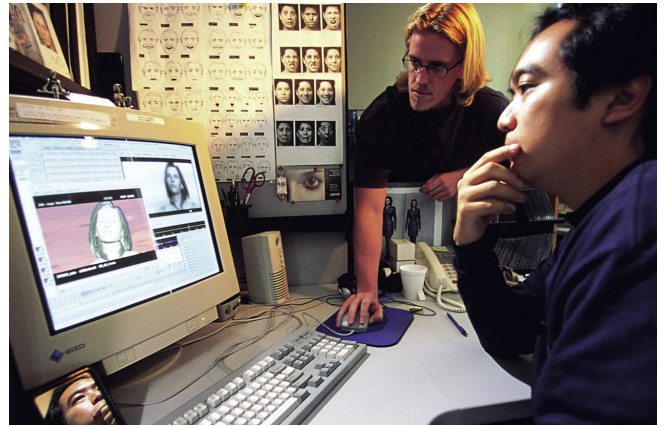
Actors wore tight-fitting black suits to which reflective markers had been applied. Those markers would be captured by a sixteen-camera setup, built by Motion Analysis. “It was an optical system,” said Scott, “and it was set up on an eight-by-ten-meter zone. We had very simple sets on the stage- doorways and platforms- and the actors would perform their scenes on those sets. Every set the characters would be interacting with in the movie had to be built on the motion capture stage. If they would be walking around a table, that table had to be built. If they had to touch a hologram on the table, we had to mark where that hologram would be. If they walked over to a window that was at an angle, we had to have something there at that same angle so that their bodies would be in the right position. Anything that was off even a little bit would mean a lot of extra work for the animators.”

One set piece built for the motion capture stage was a chair that would be seen within the cockpit of an armored vehicle. “The actual chair you see in the movie is a very thick, solid object,” said Scott, “but we couldn’t build that on the motion capture stage because something

that big and solid would have obscured the markers on the actors' bodies. So we created a kind of wire-frame chair that you could see through when the actors were in it. We put it on casters so we could have guys shake it for scenes when the vehicle is rocked by gunfire. That affected the actors' body movement- the way they grabbed onto handholds and swayed as the vehicle was rocked." Appropriate props, such as guns, were also handled by the actors and motion captured. The actors were armed with weapons that had the same heft and weight as what would be portrayed on screen, so that their handling of them would look authentic.

In many cases, the environment being depicted in a scene was much larger than the motion capture stage; and so the scene would have to be captured in multiple passes. "We had proprietary software that would blend those separate passes together," said Scott. "Also, because some scenes had a great number of actors in them, we'd have to do multiple passes, capturing only two or three of the actors at a time. If we had too many actors on stage standing next to each other, the body of one would start obscuring the markers on the body of another. So we tried to keep a certain amount of space between the performers. We'd capture two or three in one pass, another two or three in another pass, and so on, then blend those groups together for a scene with ten or more characters."

The actions of the performers were picked up by all sixteen cameras- arranged in a circle to capture the scene from every angle- and translated to low-rez models within the computer. The data was transported directly into Maya where it would be used by the animators and applied to higher-rez animation forms. "One of the things that was different about this project," observed Scott, "was that we weren't just using motion capture for stunts or background characters. We were motion capturing actors portraying the movie's main characters, and all the emotional, psychological and dramatic nuances that went along with that. Because of that, the casting of the motion capture actors was as important as the casting of the voice actors. They were really portraying these characters- they said the lines and performed the scenes, just as any actor would. The key to creating human beings was that we actually started with human beings."



Animation supervisor Andy Jones and lead Aki animator Roy Sato study a shot in progress on one of the studio workstations.

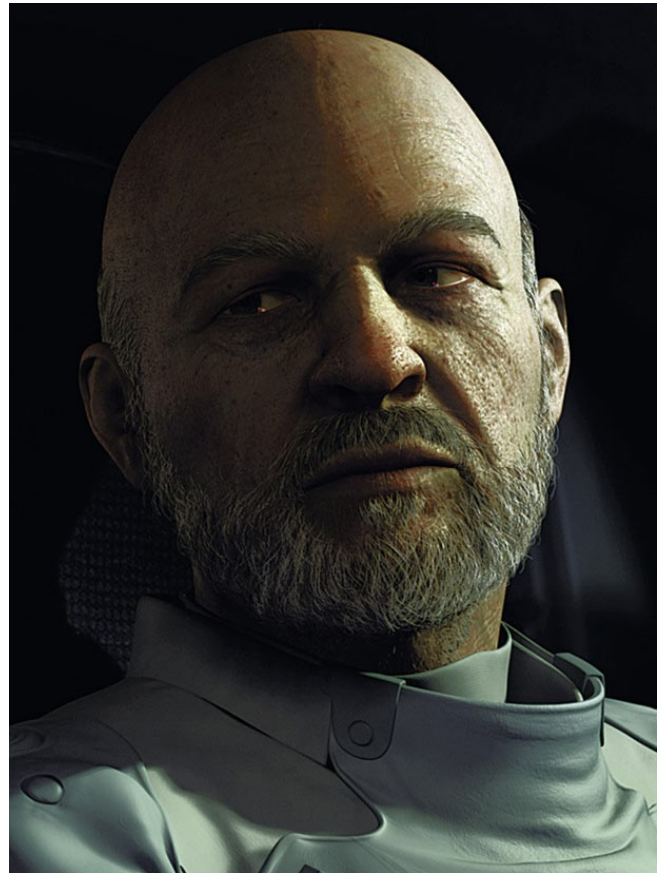
In some cases, a single actor would play more than one role. For example, Tori Eldridge portrayed both Aki and squadron member Jane Proudfoot in the motion capture sessions. “These two characters are as different as night and day,” stated Scott. “Aki is a scientist, a doctor, a very well-educated person, whereas Jane is a warrior. The whole dynamic of the two characters is very different- and so Tori would have to play those two characters very differently. It was a real acting challenge. Another challenge was when she was playing opposite herself in a scene between Aki and Jane. That was extremely difficult. There was a scene where Jane had to take something off of Aki’s belt. Tori would reach over and play that action as Jane, then in another pass, react to it as Aki. We had to plan that out very carefully to get the timing and action of both characters right.”

Though Andy Jones had joined the show with concerns regarding the viability of motion capture for animating the CG characters, proprietary tools that increased the data’s flexibility made him a believer. “I was initially against motion capture for a lot of different reasons,” Jones admitted. “I had worked with it a bit on *Titanic* and *Godzilla*, and I found that it was very difficult for the animators to change things. It was almost impossible to make adjustments, so we were more or less stuck with what was motion captured. On this show, however, the tools were much more sophisticated. We had tools that enabled us to get the motion capture into the computers and then allow the animators to work with it and change it, as needed. An animator could choose to use the motion capture data for twenty frames, then turn it off for the next thirty frames, key those frames by hand, then turn it on again. Or he could say, ‘I want the motion capture pose for every tenth frame.’ It was much more flexible, and it made the animation go a lot quicker.”

In the end, motion capture was used for all of the broad movements- such as walking and running- while more subtle body actions were usually hand-animated. “Most of the time,” recalled Jones, “we found that it was just easier to keyframe those subtle things. But, even



Supporting characters- all brought to the same level of verisimilitude as the leads- include the sinister General Hein and the dedicated Dr. Sid.



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there, the motion capture process was helpful because it allowed us to watch the actors perform a scene on stage. We'd see how they behaved, what their body language was- and the animators could take all of that information and run with it. Often, because the motion capture stage was so big, the actors would overplay their scenes; but at least the animator could get the gist of what was going on in the scene, and then he could subtle it down and keyframe it."

The most subtle of all the animation was that required for facial expression- movement so small that it could not be motion captured at all. "There are so many little things that happen in a facial expression," Jones explained. "When the jaw opens, for example, the skin doesn't just stretch down, it actually rolls over the jawbone. Temple muscles move when you chew. There are so many subtleties, and a lot of them are things that people don't even notice. But they'd pick up on it if those things were not in the animation, because we see faces every day. We know, instinctively, what a face looks like when it moves. So we did a lot of that subtle movement in the facial expressions- but, even so, it is missing certain components, and that makes the characters look less real. It is the most challenging animation to create."

Clues as to how to animate facial expressions came from the animators themselves. Embracing a technique handed down through generations of traditional cartoon animators, they would study their own faces in a mirror as they made certain expressions, then copy the perceived movements in the animation. As a result, characters picked up some of the characteristics of their lead animators. "A lot of the personality and behavior of a character came from the animator's own personality," Jones said. "Roy Sato, for example, was the lead animator on Aki- and you see a lot of Roy in that character. The timing of Aki's blinks are the same as the timing of his blinks. The way she talks is similar to the way he talks. Same thing with General Hein. Matt Hackett was the lead animator on that character, and you see a lot of Matt's personality there."



A member of earth's defense force- in full battle armor- seeks out enemy aliens in the ruins of a former urban center. Advanced motion capture technology, allowing animators to edit and alter recorded data, was used throughout the film as a source for broad human animation.

Though subtle expressions and behaviors were influenced by the animator working on a character, most of the personalities and behaviors derived from the voice talent playing the particular role. "Eighty to ninety percent of the personality of these characters came from the voice actor," remarked Jones. "It came from how they delivered their lines- that created the outline of who that character was. Even when they were not speaking, the personality of the vocal talent drove the character. Hein was a perfect example. He had several scenes in which he lost his temper; and that characteristic came from James Woods' performance."

Animators worked with an animation-resolution model, which looked something like a doll. Since the model was less detailed than the final rendered version, it could be dealt with much more easily and quickly in the computer during the animation process. A series of buttons and

sliders were set up to move various features. For facial animation, these controls were divided into categories according to areas of the face– eyes, eyebrows, mouth.

Roy Sato had a library of about fifty different pre-set expressions that he used in animating Aki. “With these controls,” Sato noted, “I could do very detailed things like control the size of her pupils or make her nostrils flare a bit. Those small details were important for Aki, since she never shows a lot of expression. She does not bulge her eyes out or have a gaping mouth. Sakaguchi didn’t like that at all. Any time I opened her eyes too wide or cranked open her mouth, he would ask for a retake. So I had to bring out her personality in subtle ways, with very small movements. Her eyebrows might move just a tiny bit, or her eyes might shift slightly. Creating these emotions and this personality with such subtle animation was the most challenging part of this project.” Sato relied mostly on the eyes of the character to bring out emotion. “The eyes communicate so much, so they were very important. I put much more effort into her eyes than her mouth, for example. That was where the emotion and expression really showed themselves, so that’s where I put a lot of the emphasis.”

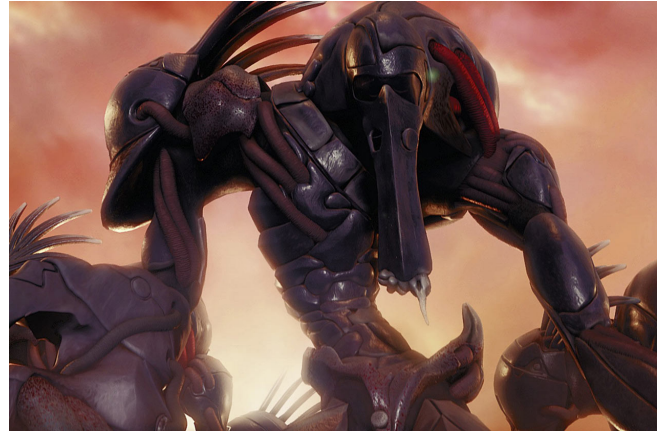
To animate the lip-sync for Aki, the soundtrack of Ming-Na’s vocal performance was brought into the computer. “Her audio track was represented by a little blue squiggle line, right on the monitor,” said Sato. “I’d also bring up Ming-Na’s footage from her recording session in L.A., and put that up side by side with Aki. Then I would go frame by frame, looking at Ming-Na’s different mouth shapes as she spoke, and trying to make the same shape on Aki. To make the mouth shapes, I could physically go through each slider for the mouth and attempt to match it up; but that took a lot of time. So I created a library of all the different phonemes, and I could just select the appropriate one. That made the lip-syncing go much faster.”

An adjunct modeling and animation chore was creating simulations for the cloth that would make up the characters’ wardrobes. Cloth was such a specialized, labor-intensive project, a wholly separate cloth team was organized. “To start,” related Kevin Ochs, “we’d get art department sketches of what each character was supposed to be wearing. Then we’d ‘build’ that with our cloth simulation that we wrote in-house. As it turned out, costumes had to be built exactly as they would be built in real life– attaching a sleeve to a jacket, for example. Each costume had to be built in pieces and then assembled. After we modeled each outfit, it was just a matter of adding the dynamics needed for specific shots. We’d apply stretching, bending, wrinkling, flapping– whatever a particular shot required due to the movement of the character in that shot. We also had wind dynamics calculated and applied, so the cloth would move in the wind.”

In the end, the cloth animation was approximately fifty percent procedural and fifty percent keyframed- though different costumes and different shots required varying levels of each approach. "Some outfits created more problems than others," stated Jones. "For instance, the tight-fitting T-shirt that Gray wears was much easier to deal with than the leather coat worn by Hein. That was a stiffer material and it flapped around; so it had problems that, after the simulation had run, the animator would have to go in and adjust by hand. But the first step was to run the cloth simulation on all the different approved animations. Those would come back rendered, and then we'd see where the problems were and basically go from there. Sometimes we'd get a shot back and it would look perfect as it was, so the artist wouldn't have to touch it. But that only happened about ten percent of the time."

On a parallel track with the character modeling and animation teams was the 'sets and props' team- supervised by Tadao Odaka- which built all of the environments the characters would occupy in the course of the story. "We did all of the modeling and texturing on the spaceships and landscapes- everything except for characters and visual effects," explained Andy Harbeck, one of the sets and props department artists. Since the virtual camera would be moving throughout the environments, they were built primarily in 3D. "We built from the foreground all the way back, painting and building in a lot of detail to create a feeling of depth. In some cases, we left sets open in the back so that if the director wanted the shot to continue farther back than he had indicated, he could do that. If nothing else, we could fill it in with a matte painting to continue the view. But, typically, we created far enough back in 3D so that any shot could, ideally, all be 3D, so there'd be a sense of perspective throughout."

Working in concert with the character animation and sets and props teams was the visual effects department, responsible for adding pyrotechnics, explosions, dust, debris, fire and smoke to shots. "The entire third act of the movie is riddled with effects," observed visual effects supervisor Remo Balcells. "And they're huge effects. We had to create large amounts of smoke and fire, explosions that filled the screen, layers and layers of dust and debris elements- and we had to do it efficiently. People don't think of columns of smoke as challenging; but when you have to produce hundreds of them in a month, it is definitely challenging."



Alien visions inhabit Aki's dreams.



In a pitched battle requiring extensive visual effects, an earth defender opens fire on an alien phantom.

Rather than attempt CG smoke and fire, production had actually considered integrating real fire and smoke elements into the CG production. "I remember that being discussed in a meeting with the director," remarked Balcells. "Before he made up his mind, he gave us a month to do some R&D, just to see if we could do it in CG. I told him from the beginning that we probably wouldn't be able to deliver super-realistic fire; but that we could give him a very convincing artistic fire. And I think we managed to do that. If we had gone with practical fire elements, they would have looked out of place with the rest of the film. Also, the fact that we went with digital gave us much more freedom in how we placed the fire and how it behaved."

In the next stop on the pipeline, completed elements from all of the separate divisions were packaged together and sent to lighting. "Lighting is basically the point in the pipeline where all the things that have been worked on individually come together in a kind of focused entity," said lighting supervisor David Seager. "For a given shot, we'd put together the set, the characters, the animation, and then blast it with light. We'd flood it with as much light as possible, because the real intention at that point was to discover problems- does a character penetrate an object as it moves past? Is there a pop in the animation? Our first job was to catch all of those things."

Once problems had been identified and fixed, the lead lighting artist for a particular shot would sit down with co-director Motonori Sakakibara to go over general lighting requirements. "They would talk about what the dominant colors were in a scene, what the intensity levels should be, what mood we were trying to get across with the lighting," noted Seager. "It was very similar to the type of conversation a director of photography would have with the director on a real set. Then, typically, we would go into the set first, without any characters, and just light the environment. Next we would identify a number of hero shots, which would define the look for the characters for the rest of the sequence. The lead lighting artist would then work on that master shot, showing it regularly to the co-director to get his input."

Lighting the flesh of the characters to make it look realistic was one of the key challenges of the show. "Characters are by far the hardest thing for us to light," Seager admitted. "Metal and plastic are a lot easier than flesh. Flesh has all those great translucent properties, as does hair. So we worked very closely with the character department, which provided the surface shaders. We might tell them: 'You know, we're not really getting what we need here. Can we adjust the surface shaders a little bit for this environment, to help pull this off?' And they would do that for us. We might be lighting an ear or something, where you should be able to see through it a bit; so we'd go to them for some custom fixes. The character-driven sequences- intimate moments in medium and closeup shots, where there's not much action- were the ones that caused the most trouble, just because of the degree of scrutiny. In the action sequences, there is so much happening, everything goes by very quickly. But there were other shots where the characters were looking right at camera, so the audience would be focused entirely on that character. In those shots, every little detail had to be right." Hair was even more difficult than flesh. Aki's long hair, in particular, not only had to reflect an appropriate rim light- depending on the lighting conditions of the scene- it also had to cast shadows on the character's face as it moved.

As always in a virtual lighting situation, cheats were employed to make each shot look its best. “For example,” stated Seager, “we have trouble making light bounce in the virtual realm. In the real world, if I’m standing next to a red table and there’s a light at the top which comes down and hits that table, a bit of red light will wash up on me. But our renderer, by itself, wouldn’t do that. So, to simulate that, we’d put a light on the top and then put a little bit of a red light underneath the table, which would wash up and give the impression that the first light was bouncing up on the character standing there. We also added fill lights, as needed– sometimes we’d hang a light right on the chin of a character as he walked around, to fill in the eyes. We were always worried about the eyes going too dark because they were so important to the audience making a connection to the characters.”

In addition to surmounting these artistic challenges, the lighting team had to deal with the logistics of working with such render-intensive shots. Simply opening a file on the computer could take up to an hour; and since those files would have to be opened several times throughout a day, the waiting time added up to a considerable loss of productivity. “That really affected the artist’s workflow,” Seager noted. “The director might say: ‘Okay, make a tweak here. I want this light brighter and I want this light positioned differently.’ So we would make that change, render it– and then sit and wait for an hour. And when we saw it– ‘Nope, that’s not quite it.’ So then it was another tweak and another hour’s wait.” One way around the waiting problem was to equip each lighting artist with two computers, so he or she could work on one while waiting for a file to come up on another. “We also applied little tricks– for example, the first time we would bring in Aki, we’d bring her in bald just to see how the light was hitting her. That saved time because we weren’t rendering the hair, which took a very long time. Aki’s hair alone consumed twenty-five percent of our rendering time for this entire movie. There were times when we all thought, ‘Why couldn’t she have been bald?’ In fact, there’s a cell block scene where the main characters are arrested, and we joked that maybe they could all get shaven and bar-coded in that scene!”

After lighting was approved, shots went to final rendering. Rather than render an entire shot at one time, each element of a shot– a character, a spaceship, a piece of set– was rendered individually, in separate layers. “We did that for several reasons,” said Seager, who also handled sequence supervising, which was where final rendering took place. “One, it made the



Wounded in battle, Aki is ministered by Dr. Sid. The digital filmmakers found replicating fabrics and creating garments to be among the most challenging aspects of the project.



Much attention was paid to the construction of environments. Manhattan– completely enclosed– is now the only human stronghold on earth.

compositing a lot easier. It also made the rendering easier for any one given layer. By the time we got to our final images, individual layers of a frame could take anywhere from one to six hours to render. If you multiply that by an average of nine layers per frame and ninety frames per shot- it became this huge, huge thing.”

For final polish and assembly, the rendered elements were sent to the compositing department, supervised by James Rogers. Overall, the compositors found that putting together an all-CG feature required more artistic input than that needed for a live-action film. “When you’re working on a live-action movie,” stated Rogers, “you get the plates in and you know what color everything needs to be because it’s been defined by the DP. You know the sky is blue and the grass is green and so on. But on this, the first time the plate really came together was in compositing. So it required the compositor to conceptualize and conceive the whole shot and make a lot of those artistic decisions. An additional hardship was that sometimes we’d have to start on shots that were not the wide shots- so we would not have an establishing shot to guide us. In those cases, the closeup had to be used to establish the shot; and we just had to hope there weren’t ramifications down the line when the wide shots finally came out of rendering.”

The compositors were also responsible for fixing mistakes not apparent until this final stage. “We’d do anything from CG fixes to key-lighting to creating elements,” explained Rogers. “We’d take hair out of a character’s chin or wherever else it wasn’t meant to be. We’d also do shadow fixes and adjust the balance of the skin versus other features on the faces. We found on the human characters that the inside of their nostrils or the whites of their eyes would sometimes get too bright; so we’d blend that back and make it fit a bit better.”

Composited shots were put out to film, then assembled into sequences by Sakaguchi and editor Chris Capp. Sound designer Randy Tom conducted a six-week dub session at Skywalker Sound, while scoring was done at Abbey Roads in London. Near the end of production, a second recording session with the voice talent was set up so that new line readings or altogether new lines of dialogue could be inserted into the soundtrack. “Once they saw the final animation,” related Capp, “the actors had a much better idea of what the performance needed to be than what they got from the storyboards and early layout- which is all they had to look at the first time they were recorded.”



In the surreal terrain of her nightly dreams, Aki discovers the source of the alien phantoms and, in the process, unlocks secrets of the human spirit.

“We projected the images from the movie up on a big screen and had the actors ADR it just like they would a live-action movie,” elaborated Andy Jones. “It was the first time some of the actors had seen the movie this far along. James Woods had seen his character before, but this was the first time he had seen the movie more or less complete. He was totally impressed.”

Even as the July release date approached and the film went through its final edits, the storyline continued to evolve- one of the benefits of an all-CG production, since new scenes could be

inserted without concern for reshoots or actors' availability. Some changes were made for technical reasons. "There was a scene in which Aki and Gray are conversing in a restaurant," Sakaguchi recalled, "with Aki eating spaghetti as she talks. But we found that it was extremely difficult to create a woman eating spaghetti in computer graphics. So we changed the setting to a gondola." Other new story points were simply the product of Sakaguchi's always fertile imagination. "There were a lot of sequences in the movie that revolved around Aki's dreams, and I was constantly coming up with new ideas and trying to improve upon what we had for those visual dream sequences."

With *Final Fantasy: The Spirits Within*, Sakaguchi and his creative team met their goal of producing a feature film cast with the most photorealistic digital human characters ever seen. It has been proposed, in some quarters, that the inevitable result of ever more photorealistic CG characters will be to put real actors out of business. But Andy Jones and others at Square scoff at that notion. "It's a really silly idea," Jones insisted. "For every character in this movie, we had to use two actors- one for the motion capture sessions and one for the voice. And it is still animation, which is a completely different medium than live-action film. No matter how good it gets, it will always be animation."

Nearing the end of his first film assignment, Sakaguchi reflected on the differences between directing a game and a full-length feature. "There were more similarities than differences," observed Sakaguchi. "The big difference was just herding so many people and ideas. When you are producing a game, there is an indisputable limit to what the hardware can do and what the computer programs can do. So you may have an idea- but if it is physically impossible to carry out that idea with the current hardware and software, you can't contest that. But in a feature film, almost anything is possible. There are not those same built-in limitations. And the people who work on it, the artists themselves, have their own ideas of how to make any idea possible. So the most difficult thing was controlling all of those ideas and bringing them together."

Hironobu Sakaguchi foresees many more computer animated features emerging from Square's new studio, as well as the birth of an entirely new form of entertainment. "What I would like this studio to produce in the future," concluded Sakaguchi, "is something in which the photorealistic imagery would become interactive- so that the viewer could choose to look at things from a particular character's perspective, for example, or be able to manipulate the camera whatever way he wanted to. There are many ways in which a CG film could allow for interactivity. At this point, it's only an idea in my head; but that's the sort of environment and entertainment I would like to create someday."

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SPEED DEMONS

ARTICLE BY Joe Fordham



Cinema has had a long romance with speed. From the gritty, high-octane classics *Bullitt*, *Two-Lane Blacktop* and *The French Connection* to the white-knuckle thrill rides of *The Right Stuff*, *Mad Max* and *Return of the Jedi*, the pursuit of velocity in film has transcended genres and become a cinematic institution. Director John Frankenheimer twice scorched his signature across movie screens, taking the art of split screen to new heights with montage designer Saul Bass in *Grand Prix*, then returning some thirty years later to plaster audiences into their chairs with the pell-mell road race that climaxed *Ronin*. Lately, director Renny Harlin has stepped up to challenge the kinetic stakes in *Driven*, providing his own take on the driving experience as viewed from the theater seat.

“When I was young and I first got my driver’s license,” recalled Harlin, “I probably drove a little too fast and I was in quite a few crashes. I also raced go-karts, and I was always crashing those. When you’re in a crash, time freezes for you. It’s like you’re running down stairs and you slip—somehow you know everything that’s going to happen and you know you’re going to fall, even though it all happens in a split second. I’ve always wanted to be able to communicate those feelings by bringing those experiences to a movie audience. Previous racecar movies haven’t had the technology to do that— to really put the audience in the driver’s seat.”

Harlin recognized the opportunity to explore the realms of speed in a script that was originally entitled *Champs*, written by Sylvester Stallone— who had previously co-written and starred in Harlin’s *Cliffhanger*. The screenplay was a pet project that the star had been developing over a number of years. The story that later became *Driven* chronicled the return of fictional racecar driver Joe Tanto (Stallone) to the open-wheel racing circuit. Lured from retirement by race promoter Carl Henry (Burt Reynolds), Tanto is enlisted to channel the untamed talents of rookie driver Jimmy Bly (Kip Pardue). Following the characters’ travails on and off the track, mentor and student overcome their demons, culminating in a race in which Tanto takes his place with Bly on the starting grid, back behind the wheel.

Major action sequences were structured around racing tournaments in five cities— Toronto, Tokyo, Chicago, Berlin and Detroit. To capture the scope and dynamism of these Grand Prix

venues, Harlin elected to gather principal performers and a skeleton film crew for a preproduction shoot, staging scenes with stars amid actual Championship Auto Racing Team events around the world. The impending racing season immediately set a ticking clock on the production schedule. Harlin led the preproduction film shoots, capturing story points and background color, and mingling actors with real race drivers at nine races across five countries. Ports of call included the Grand Prix in Miami and Long Beach, races in Queensland, Australia and Rio de Janeiro, Brazil, and the Firestone Firehawk 500 in Montegi, Japan.

“We were shooting the racetrack, the cars, the grandstands,” stated Harlin. “We were sometimes shooting with multiple cameras, sometimes from helicopters, or cranes, or cameras attached to cars. We shot half a million feet- a huge amount of footage- so that we could use it however we chose later and the audience would never know if it was from a real race or if it was staged.” Principal photography was scheduled to overlap with the Detroit and Chicago Grand Prix and the Toronto Molson Indy. Additional scenes were then allocated to a fifteen-and-a-half-mile closed track at PMG Technologies- an automotive test and research center in Blainville, north of Montreal in Canada. One main task facing Harlin during preproduction was to determine how much of the races could be achieved by live stunt drivers and mechanical effects, and how much needed to be achieved with visual effects.

Complicating the issue, Jeffrey A. Okun- who had supervised the visual effects for five of Harlin’s previous films- was unable to join the production, due to his heavy involvement with the concurrent Red Planet. “Our visual effects shot counts always grow,” said Harlin, “so I was hoping to find someone who would be as good as Jeff, in terms of managing that growth on a daily basis. We needed somebody who would be as knowledgeable and patient as Jeff to handle that workload, and we needed someone who’d be flexible, and be able to stay on budget- which is always the toughest thing.” While Harlin began interviewing prospective candidates, Okun recommended Brian Jennings, a digital supervisor on Harlin’s Cutthroat Island and The Long Kiss Goodnight, who had since become a full-fledged supervisor on projects such as Mimic, The Faculty and Scary Movie. Okun’s endorsement and Jennings’ willingness to embrace Harlin’s guerrilla filmmaking plan secured him the position.

For stunts considered too dangerous to stage live, Jennings and Harlin discussed creating miniature versions of their racing cars and racetracks, but decided that this would not be a cost-effective solution. Instead, Jennings proposed mixing computer generated cars with real cars on a real track. Also, digital composites- with actors in vehicles against bluescreen- would help sell the illusion that lead performers were driving the racecars. Harlin would film other scenes on location, towing actors in racing cars behind a camera car, using stunt drivers and full-scale mechanical effects. As Jennings prepared to relocate from Los Angeles to join the preproduction team in Toronto, Harlin began meeting with physical effects designers.

Colin Chilvers, a Toronto resident since his Oscar-winning work in England for the Christopher Reeve Superman films, caught wind of the upcoming racecar project due to arrive in his hometown. Securing a recommendation from the art department of his current production, X-Men, Chilvers met with Renny Harlin, who had already begun exploring physical effects options. “Another special effects designer had proposed the concept of using full-scale, radio-controlled cars,” Harlin recalled. “They had developed a system where you could drive a car

remotely at 145 miles per hour. The danger was that there might be some kid with a radio in the local area that would mix up the wavelengths, and all of a sudden we would lose control. So it was just too dangerous at those speeds.”

In addition to the safety issues, Chilvers advised Harlin that placing guidance systems into full-scale cars with engines would have been prohibitively expensive. Alternatives were reviewed. “We talked about using a big air cannon that was capable of blasting cars quite a distance,” Chilvers remarked. “This is what Paul Lombardi had done at Full Scale Effects for the recent movie *Charlie’s Angels*. But again, that had been a very prescribed effect, and we wanted to be a little more versatile, running two or three cars simultaneously. I suggested we’d have better control if we built the cars from the ground up, towing them on wires, which I had done on the Disney comedy *Condorman*. In the end, that’s what we did.”

On the day of Jennings’ arrival in Toronto, Chilvers introduced Darren Cranford and Clint Green to Harlin as co-founders of Keyframe Digital, a 3D animatic previsualization service in Niagara Falls. After viewing previsualizations that Keyframe had generated for *X-Men*, Harlin and Jennings welcomed Cranford and Green to the team and began developing scenes beyond Harlin’s work with storyboard artist Dan Caplan. “We prevized almost everything,” said Harlin. “We found that we could isolate what we were going to do with the actors, what we were going to do with our stunt guys, what were going to be physical effects and visual effects. We used previz all the time in preproduction, and then during the shoot we had it on set. I used it much more than I ever had before. It was a really great tool.”

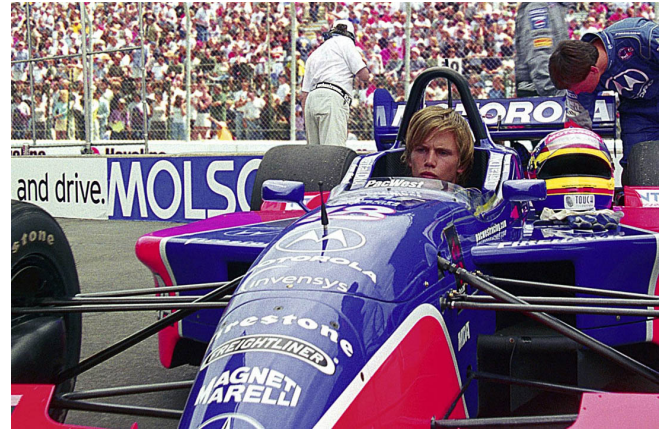


Working with visual effects supervisor Brian Jennings, director Renny Harlin applied high technology to heighten the track action in his racing film, *Driven*. Although much of the action was shot on location during or after actual racing events, crucial scenes involving principal actors and high-risk stunts were accomplished with digital effects. Among the companies involved was Pacific Title & Art Studio, which contributed crowd replication and grandstand insertion.

Cranford filled more than twenty 650MB discs with digital animation. He initiated the previsualization process by digitally scanning blueprints and aerial views of racetracks furnished by production designer Charles Wood and art director Chris Cornwell, and building scale reproductions of the environments in Discreet's 3ds Max. Cranford similarly constructed a low-rez 3D model of the film's vehicle of choice- a production-model racecar built by Reynard Motorsport Limited- scanning top-down and side-view photographs of the actual car, applying those as texture maps to represent cars from twelve distinctive racing teams, with another ten for more generic background action. He also added atmospheric details such as fog and rain, explosions and fire, as well as recognizable 3D humans, supplying a touch of humor by giving Burt Reynolds' character a toothpick in his mouth, matching his live-action counterpart in the film.

By animating track action- rigid-body dynamics combined with key-framed rotations as racecars flipped and crashed- Cranford enabled Harlin to maximize his track time at the remaining live race locations in Toronto, Chicago and Detroit. Previsualization also allowed director of photography Mauro Fiore to plan the construction of special rigs to mount cameras to cars, and to experiment with lenses best suited to the scenes.

When principal photography commenced on July 6, 2000, Brian Jennings began to gather as much raw footage as possible, shooting background plates for visual effects whose design would not be finalized until postproduction. "We had the cooperation of CART, the auto racing league," Jennings stated, "and they allowed us to mount our cameras to their pace cars. Just prior to each of the big races, when the race sponsors would give rides around the track to VIPs, Renny would give the racecar drivers little actions to perform while they were doing their practice laps. We drove out onto the track when the VIPs were halfway round- so theoretically our cars and theirs would never meet- and filmed from our pace cars. The cameras were set at the drivers' eye level, shooting at twenty-four and thirty frames per second, which we could speed up later digitally. At the Chicago Grand Prix we were able to get four laps, reaching speeds of 100 miles per hour- that was the fun part!- though we ended up having to digitally paint out a couple of pace cars in post.



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"During the Chicago race we had as many as thirteen cameras in various locations around the track, filming wide shots of the crowd and the cars. We also built a little set right in the middle of the pits, ahead of time, so we could shoot pit action right there while the race was going on. We had the track for two days after that, which was when we shot our closeup action and car-to-car shots with our own cars on the track."

Mauro Fiore and second unit cinematographer Igor Meglic collaborated with Jennings and Chilvers, stunt coordinators Andy Gill and Steve Kelso and picture car captain Gus Meunier to achieve shots well beyond the realm of standard racing coverage. "There are typically two types of camera action in a race," stated Jennings. "There's the static, long-lens shot that pans as the cars go by; then you occasionally see shots with a camera on board a car. The idea was to take those on-board camera shots and use visual effects to expand their range of movement. We had car-to-car shots; we had shots that started looking forward then panned and tilted robotically to end up looking back. We also sometimes moved from car to car, the camera mounted on a crane attached to our picture car, traveling at 150 miles per hour."

Drivers' points of view were achieved using a Panavision Frazier lens, a periscope device with an expanded depth of field. Mounted behind a driver, the lens snaked forward into his field of vision, taking in the dashboard, the steering wheel, the driver's hands and the view ahead. As many as five cameras of varying sizes were sometimes fitted to the cars, buried in the suspension or on the front and rear wings. The only limiting factors for camera placement were image steadiness and the structural integrity of the one-piece carbon fiber chassis, which could not be cut. Stunt drivers were given camera triggers in their cars, enabling them to capture key maneuvers, while video taps allowed playback, after the event.

High-speed camera car specialist Allan Padel-ford also joined the Driven road crew, supplying a racecar equipped with six outward-looking cameras, which provided a panoramic 360-degree field of view. Padelford- a skilled racing driver and winner of the 1993 Sports Car Club of America national championship- drove the three-seater rig, which was an updated version of a camera car he built in 1988 for Days of Thunder. The custom hubs, spindle and braking system



For a crash scene shot at a test track in Canada, special effects supervisor Colin Chilvers devised a practical collision in which one car was thrown high into the air. Pacific Title added rain effects and grandstands filled with spectators.



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were housed in a scratch-built NASCAR-style frame, propelled by a 500-horsepower, 510-cubic-inch Chevy engine, capable of reaching speeds of 140 miles per hour. Camera pan, tilt and yaw were remote-controlled from inside the cab by camera operator Maurice K. McGuire. An assistant riding alongside controlled focus while Padelford drove the car.

For Brian Jennings, the Padelford camera car came into its own during filming at the live racing venues. "Allan would drive his camera car around the track just prior to a real race event," Jennings explained, "which gave us a 360-degree view of the stands full of people, with all that real activity in the background. His cameras were synchronized so, when we were compositing shots in postproduction, we could stitch those angles together and motion track the entire arena using those plates."

Days spent filming arena action with empty grandstands presented Jennings with the task of crowd replication. While shooting his first race in Detroit, Jennings enlisted nine local camera operators to shoot background plates of live grandstand crowds. After instructing the operators on how to compose and photograph static, locked-off shots needed for digital replication, Jennings later found that he had overlooked a basic camera operator's instinct. "When we viewed our dailies, you could see that a few of the operators had tried to get into position," Jennings commented. "They would roll off a few feet of the crowd, but as soon as they saw what was happening on the track, they would pan right off to the cars going by." Jennings remedied the oversight in Chicago and Toronto by specifically assigning two operators using Arriflex 435s to film only crowds, covering the enormous stands filled with spectators from a number of angles, using a variety of lenses over the course of the two-hour race events.

Portable bluescreens were used on set to create quick separations between static, track-level action and empty grandstands; but overall, Jennings strove to keep the visual effects presence on set to a minimum, opting to rely on digital image tracking in postproduction rather than interrupt the dynamic pace of Harlin's directing style.

Once production wrapped in Toronto, Driven relocated to the racetrack at PMG Technologies, where a sequence was filmed for the Berlin Grand Prix. The six-minute sequence- a crucial turning point for the main protagonists midway through the story- posed a challenge for stunt drivers and the physical and visual effects teams in that the entire race was to be staged in rain. In addition to the obvious safety issues inherent in driving at high speeds around a slippery track, previsualization had shown that the distances covered in a single shot made traditional special effects rainmaking techniques an expensive proposition. "We not only had to put up rain towers wherever we wanted rain around the track," stated Colin Chilvers, "we also had to create enough water pressure to get the water as high as we needed. So we had water trucks with pumps, and put in big swimming pools as reservoirs. The scale we were working on made it a logistical nightmare, and it cost almost half a million dollars to create that rain. Renny also wanted to see the cars throw up rooster tails of water as they were speeding round, so we built some rigs on the high-banked curves to dribble water down the track to enhance that effect."

Chilvers assigned a third of his forty-man crew to rain detail, constructing stretches of rain towers that extended a quarter of a mile, spanning eighty feet per tower. Adding to the task was the fact that slip-resistant rain tires tended to overheat and explode when racecars hit dry track; so Harlin had to hit key story points in short cuts, aided by whatever tricks Chilvers' team could muster. "If the camera was static," Chilvers commented, "we found that we could cheat our rain effects by just using a lot of rain in the foreground, as long as we had a really wet track so the cars would throw out their rooster tails. We also built portable water rigs to run off the back of camera cars to help with closeups when we were towing cars or tracking with the cars. A little backlight also helped."



In a demonstration of precision driving, veteran driver Joe Tanto (Sylvester Stallone) tosses three quarters onto the track and then skids over them, embedding the coins in his tires. One of the coin pickups was accomplished by Tigar Hare Studios. Everything in the shot except the sky and some distant trees was fully computer generated.

In the last few weeks of photography, Camera e-Motion, a motion control supplier in Montreal, was contracted to conduct a two-day motion control shoot of actors seated in their Reynard racers. Based on another recommendation by Colin Chilvers, who had used the Camera e-Motion studio while directing a television commercial, Jennings commissioned company founder Marc Côté to photograph stock bluescreen plates, establishing the lead players in their vehicles, and capture elements for more elaborately designed car-to-car transitions, as previsualized by Keyframe. With the Reynard cars placed on a vibrating 'shaker' rig built by the Chilvers crew, shots were backed by one fifty-by-fifty-foot bluescreen and two twenty-by-fifty-foot bluescreen side panels. Côté spent a day and a half preprogramming the Milo motion control rig, using Cranford's animatics as a visual reference. The Milo rode a fifty-foot-long camera track, often swooping low, closing in on the drivers. A manual override, known as a 'grip stick,' enabled Côté to apply subtle camera roll to gliding camera moves.



Computer generated cars were often inserted into live racing footage, either to maintain scene continuity or avoid on-set stunts considered too dangerous. In this shot, the blue Motorola car-driven by Jimmy Bly (Kip Tanner), a rising star on the circuit- is a CG vehicle added by Digital Dimension to an otherwise live-action plate.

The efficiency of the Milo shoot- thirty setups in two days- led Jennings to assign Côté additional scenes on the PMG track using Camera e-Motion's proprietary camera-encoder, an eight-axis motion control rig based on a standard Fisher 10 dolly and a Panavision Panahead. The system recorded motion data in real-time using ActiveMotion, a Windows software

application designed by Camera e-Motion engineer Nickolas Landry. Scenes were also encoded for a sequence that concluded the film, shot in further rain conditions at Circuit Gilles Villeneuve Formula One racetrack on Notre-Dame Island, west of Montreal. This rounded out the total accumulated footage for visual effects, which amounted to 1.5 million feet of film.

Earlier in preproduction, Harlin and Jennings had defined the racecar crashes as the most complicated area of visual and physical effects collaboration. It was not until filming was underway on a scene known as 'Memo's crash'—Chilvers' first live crash effect during the rain sequence on the PMG racetrack—that the final methodology became apparent. "Renny had just come off of *Deep Blue Sea*, which was a very demanding mechanical effects movie," Jennings recalled, "so before we started shooting he felt that CGI would be a more controllable way of creating crashes. It eventually turned into much more of a joint effort between Colin and me. The truth is, Colin's really good at what he does, and there were simply things that he could do better. As Colin and I dissected the crashes, we decided that practical effects would work well for the beginning of an impact, where the cars hit each other or collided with a guardrail. CGI would take over as the cars went tumbling through the air and then, when the car landed on the ground, it would be practical again. Eventually it reached a natural balance."

The near-fatal crash of teammate Memo Moreno (Cristian de la Fuente) is a crucial factor in steeling Jimmy Bly's resolve to defeat arch rival Beau Brandenburg (Til Schweiger) in the film's third act. The scene called for a glancing wheel-to-wheel collision with Bly's vehicle that sends Memo's car headlong into a guardrail, flips it fifteen feet, then brings it crashing down into a cartwheel that drops it blazing into a river.

Preparation for the crash started six weeks before shooting. Chilvers purchased a number of wrecked racecars from the Indianapolis 500 and had the pieces shipped to his Toronto studio, The Effects Group. Intact body parts were salvaged from the wrecks, then molded directly in fiberglass, pulling basic shapes from hubs, the upper chassis, front and rear wings and aerodynamic skid plates underneath. Chilvers' team built twelve steel frameworks for the cars, with working suspensions and simple steering systems capable of being operated from a towing mechanism. Real racing tires were affixed to axles, then fiberglass body parts were applied. "We built our dummy cars very similar to the way the real race cars were built," Chilvers commented. "We used very thin tubular steel for all the metalwork, welded in such a way that we knew on impact it would fall apart, although where we strapped our dummy person in was pretty bulletproof. After that, the sides went on, the nose cone, the engine covers and the wheels; so when we crashed the cars, they would come apart very similarly to the way that the real cars would."

Chilvers plotted the trajectory of Memo's crash by mapping out a path across the PMG racetrack for the 600-pound dummy car to follow. Technicians drilled metal plates into the road surface, anchoring a series of pulleys, which were geared to double the speed of a towing vehicle. Then they fastened ¼-inch-thick steel cables to the front axle of the dummy car, while a ½-inch guide cable trailed from the rear and three-eighths-inch cables extended from the side to 'diverter' pulleys, used to make the racecar veer into the guardrail. Harlin put ten cameras around the scene- two of which would later be digitally erased, peering down from cranes overlooking the impact zone- and a four-wheel-drive truck made ready to tug Memo's car to its doom.



Another Digital Dimension shot- a point of view as Bly weaves his car through others on the course- featured CG vehicles only, composited into live photography of an empty track.

Chilvers' team prepared four versions of the crash car. The first was loaded with pyrotechnic charges to emit a spray of sparks from its intake vents. The tow-truck accelerated to forty miles per hour, doubled by the pulley system to eighty, and pulled the car into the guardrail- satisfying Harlin in only two takes. "The car bounced up onto the rail and onto its nose, skidded along with sparks flying- it was really terrific," stated Brian Jennings. "It was so spectacular, all I could say was, 'Thank God we didn't try to do it entirely with CGI!'"

Jennings initiated the digital production line simultaneous to the start of principal photography by contracting Viewpoint- renowned for its digital facsimiles of automobiles, produced for the exacting standards of television commercials- to create a digital model of the hero Reynard car. Val Taylor, vice president of Viewpoint creative services, spearheaded the Driven assignment with project leader Wayne Hammer. "Brian tried to get us CAD data from the actual car manufacturer to build from," related Taylor, "but when that was not possible he sent us technical drawings, lots of photographs and 1/18-scale die-cast replicas of the Reynard car. We generally like to digitize the full-scale object, especially if we're trying to match live-action, but we couldn't in this instance. So we painted half the model gray, marked it up for scanning, drawing a grid over the painted area, scanned that surface with our point-by-point digitizer, then took that raw data and cleaned it up to produce our 3D models."

With the digital model in hand, together with the edited live-action crash footage, Jennings contracted digital vendor Pixel Magic, a division of OCS Freeze Frame, to develop airborne shots to link the physical effects at the beginning and the end of Memo's crash. "Renny and I came up with the idea," said Jennings. "We wanted to combine a Matrix-type frozen motion effect with something that looked like crash test footage you might see on Discovery Channel." The concept was to freeze Memo's tumbling vehicle in midair, enter the driver's point of view and capture the sense of time-dilation in one uninterrupted cut. Pixel Magic visual effects supervisor Raymond McIntyre,

Jr., a racecar driver himself for eight years, responded by assigning CG artists Kevin Kipper and Juan Vargas to create previsualizations in-house, which he edited into Harlin's footage and handed back to Jennings. As the sequence took shape and evolved into a progression of twelve cuts, CG supervisor Mike Hardison led an initiative to develop a photorealistic animated model of the car in LightWave based on the Viewpoint model and photographic reference.

The first shot in the sequence called for a track-level view of Memo's left front wheel clipping the right rear tire of Bly's car. For this and subsequent shots, the Pixel Magic 3D team also created a digital projection map of the racetrack background, generated as a planar map—projecting layers of location photography onto a digital reconstruction of the racetrack—onto which 3D cars were tracked and composited with camera shake and digital rain. The action then cut to a reverse angle of the scene from Memo's cockpit as he veered toward the guardrail—a 3D move on the planar map, composited with a bluescreen cockpit view.

Seen in a wide practical shot, the dummy car then collided with the guardrail. Pixel Magic digitally removed tow cables and camera cranes, and enhanced the scene with particle-animation rain, subtle wheel mist and a reflection pass to enhance the sheen of the track. In the final frames of a low-angle cut of the dummy car crashing into camera, Pixel Magic added jagged, motion-blurred spark trails to bring the impact right into the lens.

The tenth shot in the crash began a sequence of fully computer generated images—looking down onto the car as it rebounded in slow motion from the guardrail, tail-end first, above the track. Hardison and his team added cockpit and interior detail to the basic model of their 3D car for the shot. By matching live-action damage on the nose and fuselage, animators created a flapping chassis panel, tracked in live-action pyrotechnic elements, duplicated live-action flying debris and animated the car through a field of suspended raindrops. Rain particles were generated in foreground, midground and background layers, as volume-shaded particle animation, with foreground drops occluding and refracting the environment. Other digital cars were added below, racing by in real-time at 200 miles per hour. "Renny wanted the scene to have what he called a 'disassociated beauty,'" related Hardison. "Everything was timed according to what Memo was experiencing from inside the crash, contrasting the other drivers' experience on the track, which gave us two levels of time."

Bringing the viewer further into Memo's sense of suspended time, Pixel Magic compositing supervisor Todd Vaziri devised a dynamic transition to end the floating, sailing car shot. "I added a little horizontal vibration in the outgoing shot," explained Vaziri. "It starts small, then ramps up, and just at its apex, the camera zooms into a particular point in frame—in this case the driver's head. We then come right back out the same way, snap back into position on a shot of Memo's eyes, and the vibrations cease. We called it a 'slingshot,' because we were building a lot of tension, then letting it go. It was a lot more dynamic than a cut, and Renny used it a few other times in the film."

The closeup of Memo's eyes—with a reflection of cars ripping past below—cuts to a vertiginous point of view of the car descending nose-first onto the track. Using another live bluescreen cockpit element, Vaziri composited the cockpit against CG cars traversing a projection-mapped background, but in this case re-timed the foreground action, separating the steering column,

reanimating the driver's hands and the flashing dashboard lights to reflect Memo's time-dilated state. The addition of subtle rain hits to the visor, and the animation of tire tracks momentarily carving out dry trails on the wet track below, also helped sell the authenticity of the shot. This level of detail led to composites in excess of a hundred layers, requiring Pixel Magic visual effects producer George Macri to establish all the elements for each shot and then follow up to ensure on-time delivery.

The camera then cut low onto the track, smashing Memo's car from its slow-motion free-fall in a computer generated shot, contrasting the grace of the previous shots by emphasizing gravitational forces. Cutting wider for a view of the action seen from the infield, Pixel Magic tracked 3D cars speeding by on the racetrack and added a 3D version of Memo's car as it tumbled off the track.

"That 3D car was doing aerobics," commented McIntyre. "It bounced on all axes and seemed to defy realistic inertia until we added our camera move, making it look like the camera operator had all of a sudden caught it all on camera." Hardison's team mapped out damage centers on the 3D car, defining where the vehicle had to break up as it hit the ground, so that every time it hit, it could spout debris and remain accurate to the final damage zones on the real car. Vaziri added sparks to a car on the racetrack in the background, simulating damage from the glancing blow from Memo's car. After the addition of smoke and rain, and dirt hits from the Pixel Magic archive, Vaziri then animated the documentary-style camera move, gleaned from viewing real-life car crash footage, zooming in and adding digital motion blur as the camera panned right to left. Memo's crash concluded with a closeup of the 3D car cartwheeling into camera. This cut to a practical effect staged by Colin Chilvers' team, which propelled a burning dummy car off a ramp atop a thirty-foot embankment and launched the vehicle through the trees, like a fiery meteor.

Postproduction of Memo's crash spanned four months at Pixel Magic, giving rise to another forty-five shots throughout the film. A total of nine digital vendors would eventually contribute to Driven, providing more than 630 shots- up substantially from the initial estimate of 250. To help manage the load, Jennings engaged visual effects producer Matthew Hullum, with whom he had worked on The Faculty, to join him in establishing a base of operations back in Los Angeles at Skye Partners' The Lot, formerly Warner Hollywood Studios. Hullum's initial duties included building a file transfer protocol website, working with visual effects editor Shannon Leigh Olds to compile all of the production footage and make it available on line, with the Viewpoint Reynard model, for prospective vendors. Digital effects supervisor Jeremy Burns and visual effects coordinator Ernie Russo also joined the team, setting up an in-house visual effects department at The Lot, utilizing six Macintosh G4s to provide inexpensive digital composites. The initiative proved to be a godsend, enabling the output of some 200 shots- from 2D building replacements to 3D wheel smoke.

"At the time I came on board, Brian had already done some preliminary work during production with C.O.R.E. Digital Pictures and Command Post Toybox in Toronto," Hullum remarked.

"C.O.R.E. created a digital car, Toybox created a digital grandstand and composited the shot for a cut in the teaser trailer. We later modified the shot in-house, using a different car and splitting it into two cuts for use in the Detroit race. Brian also had been talking to a few Los Angeles

effects houses, but that was about the extent of where we had progressed with the vendors. Once preproduction started and we had an idea of the extent of the effects, we decided to handle a lot of labor-intensive, time-consuming work in-house—like tracking and roto—adding computer screen displays, wire removals and camera removals. Then, by November, we were ready to start contracting outside help.”

High on the agenda was the quest for facilities capable of generating photorealistic digital cars that would be able to withstand scrutiny alongside live vehicles filmed on location. Jennings selected two takes of racing action to put potential vendors through their paces. One, an aerial view drifting over a pack of racecars, required vehicles to be inserted and presented a tracking challenge; the other, a closer, locked-off angle on the track, was a test for photorealism. Jennings presented the results to Harlin. “Brian challenged me,” Harlin recalled. “He said he’d give me a thousand dollars if I could tell which cars were CG and which were not. He had added digital cars to footage I had shot myself; but I had shot so much that I couldn’t remember the original plate. I guessed wrong three times.”

Sold on the realism of the digital cars, Harlin worked with action sequence editor Steve Gilson to orchestrate vehicle choreography. Gilson produced Avid animatics—crude 2D animation—blocking out digital car placement by using 2D rectangles with circles for wheels animated on top of live footage. Objective animated plan-views clarified the timings. Hullum posted the animatics on the Driven website, making them available to MetroLight Studios and Digital Dimension, each of which were awarded thirty shots of digital race action.

“We selected the locked-off shot for our first test shot,” related MetroLight CG supervisor Chris Ryan, “which allowed us to implement more cars and devote our time to texture-painting, particle effects and animation. We integrated seven cars into our test, including one car spinning out and smoking. We set up the car using Viewpoint’s polygonal model. We built a skeleton inside it, so the tires and suspension could bounce and shake and the car could dip while the tires stayed put, and we set up controls on the car itself. Once we worked out the initial texture painting from photo reference of the real cars, we found that we could paint a car in a day; and we completed the test in about two weeks. This paid off later in production, because we had resolved a majority of our technical issues in a relatively short time. After that, the biggest challenge was tracking.”

MetroLight lead technical animator Jerry Weil supervised texturing and lighting in RenderMan, referencing live footage from cuts surrounding the visual effects shots wherever possible. One shot at the finish line of the Toronto race, looking over the shoulder of the checkered flag and panning with the winners, required the winner to be painted out and replaced by Bly’s distinctive blue-and-red liveried Motorola car, featured later in the pack. “We had a lot of shots where we were repositioning two existing cars closer together to create more tension, so they’d be neck-and-neck,” Weil stated. “We’d paint out one car, roto around it and shift it over, matching the rotation of the wheels. When we composited them side by side with CG cars, the saturated colors needed very careful color correction, because the real cars were so vivid they tended to look more fake than the CG cars.”

While faced with a similar challenge, Benoit Girard, visual effects supervisor at Digital Dimension, and his visual effects producer Jerome Morin, tackled the assignment from a different perspective. “Matt and Brian approached us after having seen some work we had done for NASCAR,” noted Girard, “so they had seen that we could create photorealistic cars. We had to prove to them that we could handle some difficult tracking shots, as well.” As an early test, Digital Dimension composited a pair of digital racecars into a nighttime helicopter view traversing downtown Chicago, establishing the Bly and Tanto street race. Girard’s team tracked the shot in two days and completed it in a week, assisted by the use of Boujou, an automatic 3D camera tracking and calibration system, which Digital Dimension had been alpha-testing for software manufacturer 2d3, a division of Oxford Metrics Group. “Boujou gave us analytical tools that allowed us to extract camera lens and camera motion data very quickly. It really gave us a great handle on the shot.”

Digital Dimension modeled its 3D cars from Viewpoint’s wire-frame data and developed animation controls in ReelMotion, a motion simulation software produced by Motional Realms in Phoenix, Arizona. The simulator allowed Girard’s 3D team to drive the cars, again exploiting the cars’ natural physics. Digital artists applied textures and logos from production photographs and a proliferation of racing websites, then lit and rendered the racecar models with ray tracing to cast natural shadows and reflections.

Jennings and Hullum also awarded fifty shots to Amalgamated Pixels, including a complicated composite of digital car choreography during the Firestone Firehawk 500 in Japan. At the climax of the race, Bly puts on an excessive burst of speed, locks his brakes, crashes into a wall and is passed by Tanto’s car before reaching the finish line. Harlin filmed Bly’s crash as a physical effect on the PMG racetrack; Tanto’s car was also shot driving past the wreck. To create the effect of Tanto reacting to the wreck, Amalgamated Pixels supervisor Derry Frost took a moving shot of Stallone giving a sideways glance, filmed with the camera mounted to his car, and combined this with a digitally manipulated background crash.

Frost’s 2D team first rotoscoped Stallone and his car from the moving background, then took a shot of Bly’s stationary crashed vehicle and created a clean plate by painting out the wreck. 3D artists modeled a digital facsimile of the wreck, warping and deforming the Viewpoint model and mapping it with photographic textures, then tracked this into the cleaned-up background plate. By sliding Bly’s crashed car along the racetrack, animating falling debris, and blending existing smoke back over the top, the 2D team keyed in the foreground element of Tanto and blended the two layers, matching motion blur in the foreground plate.

Pixel Magic produced an even more extreme layering of digital racecars for a multiple car pile-up at the height of the Detroit race. The sequence was filmed as a practical effect on a straightaway of track at PMG, with a dummy car smashing into a crash barrier and taking to the air. Initially, only a few digital cars were to be inserted zipping by, but this number began to grow. "Memo's crash was so spectacular in the middle of the movie," recalled Ray McIntyre, "Renny realized that the end of his movie no longer had the same impact. So he asked us to elaborate our plans for Detroit, to give the final act a little extra punch."

The physical effect of three cars piling into the railing was accented by a domino effect of CG cars careening to avoid the wreck. The straight orientation of the track at the crash site allowed editorial cheats to combine multi-camera cuts of crashes filmed elsewhere on the track, occasionally bridged by CG cars flying from one setup to another. The sequence amounted to seventeen rapid cuts, creating an eleven-car mêlée. "We didn't have to create any synthetic backgrounds," said McIntyre, "it was all real-time carnage. We added cars and a tremendous amount of tire smoke, obliterating visibility so drivers couldn't tell what they were heading into. They just head into it blind- but somehow Jimmy makes it through."

The climax of the Detroit race featured two of five digital racecar shots produced at Tigar Hare Studios, under co-supervisors Michael Tigar and David Hare. Working from a background plate that featured a helicopter shot of Brandenburg's Target car cruising by the grandstands, artists painted out the car and created a match-move in 3ds Max- derived by gauging placement of lampposts strobing past the stands. This enabled the addition of three digital cars, Brandenburg and Bly neck-and-neck, with Tanto spinning out behind, streaming 3D smoke and marking the road surface with tire rubber. Each digital car was mapped in RenderMan with sixty texture maps, detailed down to the brake pads, with an additional twenty texture maps allocated to the 3D model of the driver- incorporating helmets, seatbelts, logos. This allowed Tigar Hare to render its CG cars to appropriate degrees of realism for wide, medium and closeup shots, sometimes even fooling the artists themselves.



Look! Effects used digital image processing to achieve a subjective tunnel-vision effect described as typical of the high-speed driving experience by a number of professional racecar drivers.



Jimmy Bly's teammate, Memo Moreno (Cristian de la Fuente), suffers a near-fatal crash. Although select shots in the sequence featured a practical vehicle rigged by the special effects team, views of the car airborne and tumbling were achieved with a digital model animated by Pixel Magic.

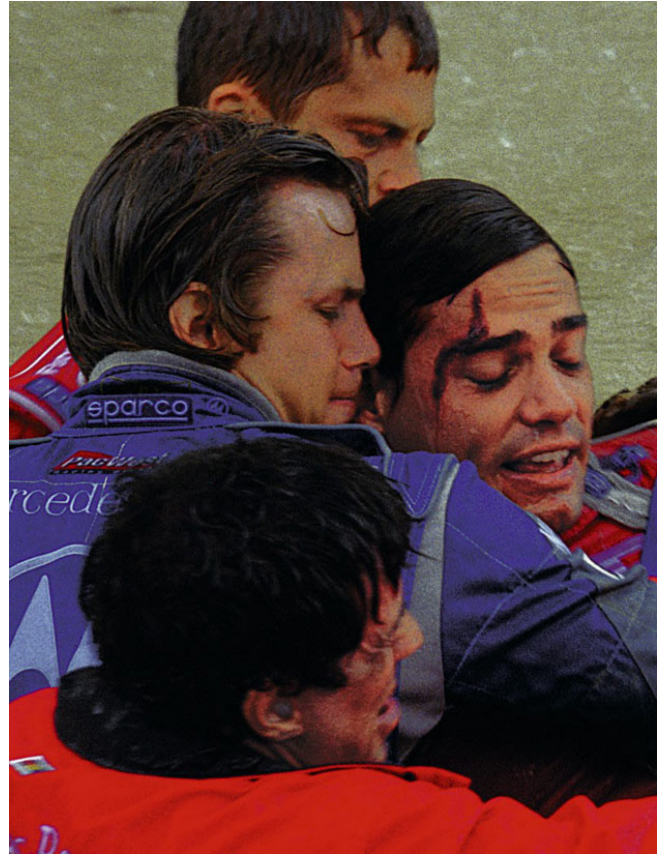
Following their helicopter spin-out shot, Tigar Hare created a dizzying overhead tracking view of the Bly and Brandenburg cars closing on the finish line. The shot ramped to 1000 frames per second, decelerating the action, plunged to an extreme low angle on the track, then returned to normal speed, allowing cars to zip by as Tanto's vehicle spun right at camera. The first 59 frames of the 180-frame move incorporated live imagery from a wide down-angle of the track. Motion blur helped disguise a transition from the overhead view to a textured 3D model of the grandstand and track. Textures were rendered in a series of displacement maps.

Another of Tigar Hare's full

3D shots occurred during Tanto's earlier test laps in Toronto, where he flips three quarters onto the track, then brakes and skids his car over the coins, embedding them in his tires in a display of precision timing. Tigar Hare created a straightaway of track and surrounding walls for a shot that starts with an ultra-closeup of one of the quarters. As Tanto's car approaches, the coin begins to vibrate. Then the camera jibs up and pans to a worm's-eye view of the car flashing by camera. The Tigar Hare team generated a 3D coin by scanning a quarter as reference, then created a high-resolution texture map in RenderMan to simulate physical displacement and spectral highlights, adding realistic discoloration to the coin's serrated edge. The coin was animated to vibrate in perspective to a 3D road surface, as the 3D car flew toward camera, wings vibrating, passing a 3D textured brick wall to camera left, stock foliage behind a chain-link fence to camera right, 3D cement borders and tire marks on the road. Tigar Hare also added secondary movement to the background, riffling 3D advertising banners and blowing wind through CG trees.

MetroLight also selected RenderMan for scenes creating motion blur for full-frame closeups of 3D racecar tires seen in full flight, hubs inches apart, Ben-Hur-style. "We created our own NURBS model of the tire for closeup shots because the polygonal model looked too square," related Jerry Weil. "We had to create our own artwork for the 'Bridgestone' lettering on the tire walls to make the motion blur look real. I wound up painting solid stripes around the whole tire, because usually they were spinning so fast you'd never know the difference."

Digital Dimension full-synthetic race action was featured in a later scrape during the climactic Detroit race, when Brandenburg forces Tanto off a curve. After establishing road positioning with a car composite in an overhead helicopter shot, Benoit Girard's team created a full-3D track-level view of a section of curved track with cars as Tanto takes to the air and lands on the grass. Fighting to regain control- a bluescreen composite of Stallone and 3D background, seen from behind Tanto's helmet - Tanto veers back onto the track. A virtual camera then flies through the front suspension of Tanto's car- a 3D vehicle in a live plate- glimpsing the damage done to it, before panning 180 degrees to observe Tanto overtake Brandenburg and rejoin the race. Digital Dimension tracked location photography in Autonomous Effects' SceneGenie, which translated hurtling camera moves into the 3D realm and allowed 3D cars to be added with appropriate camera shake and shadows in 3ds Max.



Fellow drivers abandon the race and rush to help Memo when his crashed car plunges into a river, trapping him inside. Although Joe Tanto was to have been one of the rescuers, and the scene was shot that way, a postproduction choice led to his excision from the scene. Look! Effects extracted Sylvester Stallone from one key shot and restored the obstructed imagery behind him.

For another angle in the Detroit race, setting up Bly's car looming behind Brandenburg's, Digital Dimension digitally created an environmental distortion for a shot that tracked up the nose cone of Bly's car while zooming out in The Manner of Hitchcock's famous Vertigo effect. "We added spinning CG tires to Brandenburg and Jimmy's cars, which were shot against bluescreen," related Girard. "We rotoed around Brandenburg's helmet, which was chrome reflecting the bluescreen, and created a reflection map by building a distorted 3D environment around it. To get the push-in to work realistically with the background plate, we had to zoom out on the background as the camera moved in on Brandenburg, creating a wide-angle perspective shift as the foreground distended into camera. Then, as we moved past Jimmy to the car behind him, we passed beneath an advertising banner hung above the track, and animated a shadow to sweep over them both."

Jennings and Hullum turned to Pacific Title & Art Studio to handle the creation of crowds- often filling empty bleachers in fast-moving background plates. Rodney Montague, digital producer at Pac Title, flew to Toronto to meet with Jennings during principal photography, armed with his experience replicating sports venues for the recent football films *Any Given Sunday* and *The Replacements*. The studio's longstanding reputation for top-notch 2D compositing won them fifty shots, overseen by visual effects supervisor Mark Freund and 2D supervisor Matt Linder.

A typical crowd addition began with an examination of the plate to determine if it needed 2D or 3D tracking. A parallax move, where foreground and background elements displaced each other during a camera move, often required a 3D track due to the documentary style in which scenes of empty bleachers were captured on location. Using the pool of locked-off crowd plates- organized by race and city, and presented as an array of about sixty stamps on the Driven website- compositors built up crowds, sometimes cutting and pasting single rows of spectators. These textures were then composited to the matchmove, and foreground elements were roto-scoped and keyed back over the top.

"One of the biggest challenges we had in our crowd replication shots was lens distortion," Linder remarked. "A lot of our empty background plates were filmed with the camera sitting right on the car with a 14mm lens- which allowed the filmmakers to get the car in the shot as well as all the environment around it; but the distortion was extreme. We had some tricky shots



Fellow drivers abandon the race and rush to help Memo when his crashed car plunges into a river, trapping him inside. Although Joe Tanto was to have been one of the rescuers, and the scene was shot that way, a postproduction choice led to his excision from the scene. Look! Effects extracted Sylvester Stallone from one key shot and restored the obstructed imagery behind him.

like this in the Japan race, which was actually filmed in Chicago. As a result, not only did we have to add crowds to empty grandstands, we had to replace a big parking structure, add some mountains and sky, and change a couple of bleachers that said very clearly, 'Chicago Motor Speedway.' None of it was square, which made the shots very hard to track because everything was nonlinear as it warped past camera."

Pac Title created seven matte shots of Japanese locations, incorporating stock shots of mountains surrounding the Montegi racetrack. For a quiet scene preceding the race, matte painter and compositor Rasha Shalaby also created a view of a nighttime Tokyo City Square based on a shot of the Toronto County courthouse. The slowly craning dolly shot required meticulous rotoscoping to separate three arching structures and a foreground pond from the plate, allowing Shalaby to add city lights behind the courthouse and reflections behind a scattering of lanterns floating in the pond.

The 2D work extended into 3D for an aerial view at the onset of the Berlin race. The drifting helicopter shot revealed the flurry of activity preceding the Berlin Grand Prix but had been filmed in Canada at the desolate and largely barren PMG racetrack. Shalaby filled out the grandstands and added pre-race action by sampling aerial footage shot in Toronto and painting a number of structures in 2D.

Pac Title grandstands, built in Maya and composited in Shake, were also featured in the collision of a racecar- driven by real-life Formula One professional Max Papis, who was cast in the film- with a stationary vehicle during the Berlin race. Harlin staged the crash as a practical effect on an empty straightaway at PMG, covered by multiple cameras that resulted in a montage of eleven cuts tracing Papis' car as it took to the air. Tracked behind the scene- often through heavy motion blur, rain and flying debris- the spectators in the grandstands were cloned from a group of fifty extras decked out in rain gear and umbrellas. Artful cut and paste by compositor Jennifer Law helped disguise repetition of yellow rain slickers and umbrella action. Mark Freund also joined Jennings for an additional crowd shoot in the football stadium at Pierce College in Woodland Hills, where specific crowd actions were filmed to add to the scene. The Pac Title grandstands later became part of a 3D projection-map created by MetroLight Studios for Papis' point of view of the crash, seen in the last seconds before collision.

For certain aerial grandstand shots, featured in the Japan and Germany tournaments, Pixel Magic employed a completely synthetic approach to re-creating crowds. "We would have preferred to create our crowds using live plates," related Ray McInyre, "but our grandstand shots had severe perspective changes, so it would have been glaringly obvious if we'd have used 2D people. CG artist Jim Gorman came up with a technique to create digital people with umbrellas with a little random motion to them. Once we'd done that R&D, it was relatively easy to track the stands into plates with Realviz MatchMover then place them into shots with the correct perspective, adding 3D crash barriers, flags and in-field tractor-trailers."

Pixel Magic also needed to add digital rain and car spray to its Berlin grandstand shots- a duty that extended to a number of other digital vendors collaborating on the sequence. Pac Title produced rain with a particle system in Maya, choreographing layers of rainfall in 3D to

appropriate speeds for slow-motion composites in the Papis crash. MetroLight utilized motion-blurred particles and atmospheric haze in their Berlin track action. Tigar Hare created thirty interactive 3D rain and mist effects, enhancing physical effects and exaggerating rooster tails.

Additional rain scenes were awarded to Look! Effects in Hollywood for the rescue sequence that follows Memo's crash. Incorporating helicopter and handheld shots, the sequence called for extensive tracking to allow the addition of 3D rain to enhance physical effects as Bly and Brandenburg struggle to free Memo from his wreck, half submerged in a river. Heightening the drama, Look! and Pac Title added a burning tree that threatened to ignite fuel leaking into the river. Look! co-supervisors Henrik Fett and Max Ivins and 2D supervisor Christopher Ivins filmed pyrotechnic elements, including a fifteen-foot-tall miniature tree, set ablaze and photographed at 120 frames per second. Pac Title tracked the flames to match charred branches in the plates, blended behind layers of digital rain.

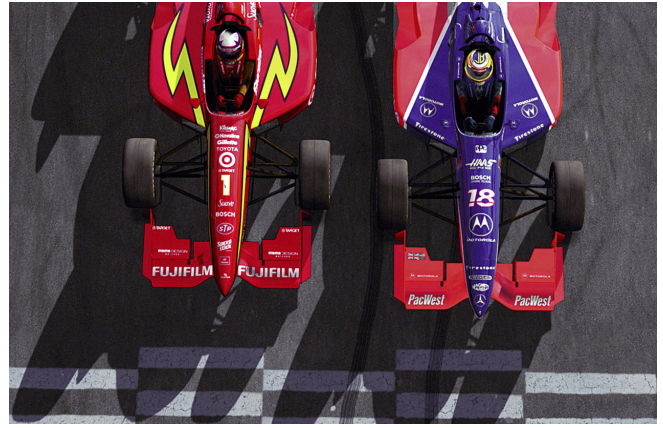
An editorial revision to the rescue sequence called for complex paint effects in six shots where Look! removed Joe Tanto from the scene to better emphasize Bly's heroism. Harlin shot the scene with Stallone submerged to the waist, interacting with the other actors and the wreck. Look! executed the removal entirely in 2D, sometimes sampling textures using Adobe Photoshop to fill areas once occupied by Tanto, sometimes warping geometries in Silicon Grail's Chalice. In one shot, compositor Isabel Vandernoot rebuilt the entire back of Bly's racing jacket by re-creating tailored sections of the garment in 2D, tracking, animating and warping them to deform with the character's movements- filling one third of the frame. Concluding the sequence, Look! also created a sheet of fire- filmed by spreading rubber cement on concrete, igniting it with lighter fluid and directing the blaze with air movers- tracking this to the plate, prior to a practical explosion.

The most prominent Look! Effects assignment, seen in seven shots in races throughout the movie, was a signature effect known as 'driver vision.' Originally scripted for three key moments in the story, once with each of the main three drivers, the concept grew to become another visual metaphor for expressing Harlin's subjective driving experience. "Drivers talk about this area that they focus on when they race," Jennings noted. "They see one area on the track that's clear and everything else turns into a blur. We contracted Look! to produce several versions to represent that effect, and they came up with a really beautiful test that Renny loved."



Tigar Hare added computer generated rain to a number of shots in a race sequence scripted to take place during a storm. Practical rain effects were created on location, to the extent that they could be rigged over long distances, but nearly all of the effects houses on the show provided supplemental rain to one shot or another.

Working from footage of a racecar's point of view speeding around the track, Look! visual effects producer Mark Driscoll assigned the Fett and Ivins teams to spend a week conceptualizing what eventually amounted to twenty-six combinations of 2D and 3D motion tests of the background plate, experimenting with color, saturation, blur and warping effects. The winning concept incorporated a rain element. "As the driver began to focus on the center of the road," Ivins related, "the driver vision effect started to ramp in, and everything on the periphery blurred out. The center of the road then became his center of attention, moving by in real time, and the past and the future blended together around him, because they were less important. We decided, by adding rain, the rain itself would seem to slow down and almost stop in midair because the driver's real focus was on the road, which would still be streaming by at 200 miles per hour. It was a nice subjective juxtaposition."



Jimmy Bly edges past his arch-rival to win the final championship race in an all-CG photo finish created by Tigar Hare.

A number of other standout visual effects peppered the movie, some of which were fueled by an early test screening, which elicited an enthusiastic audience reaction and led Harlin to further rev the racing action. One such scene, rolled into the Pierce College shoot, followed a crash-launched racecar tire hurtled skyward and into the stands during the Detroit race. Utilizing a 14mm lens on a three-axis Libra III remote control camera head, Jennings created a swooping crane shot, lifting up from ground level, swinging up over the crowd, then descending as spectators scattered. Using two selected takes, based on camera move and crowd performance, Pac Title combined the upward swing of one move with the descent of another, match-cutting the blend at the apogee of the arc. After digitally removing a prominent 'Pierce College' sign on the stands, Pac Title tracked the camera move and handed it off to Pixel Magic, which animated the rogue 3D tire spinning through the foreground toward the terrified crowd, the camera in its wake.

The Chicago street race presented a handful of isolated digital effects to MetroLight in a sequence in which Bly's speeding racecar passes over a series of manhole covers. By the sheer force of its downdraft, Bly's car creates suction sufficient to pluck the heavy iron discs out of the road and spit them out at Tanto's vehicle behind. Modeled in 3D, with a 'City of Chicago' logo embossed on their surface, The Manhole covers were animated over existing ones in the street, then timed to fly over Stallone's head in reverse angles on Tanto's car. Aside from these effects and a single head replacement by Pac Title- helping place Stallone inside his vehicle- the street race was accomplished primarily live, with stunt doubles performing maneuvers that visual effects had not originally deemed possible.

Keyframe Digital furnished one final detail, seen prominently throughout the film on Jimmy Bly's laptop screen- an on-screen previz tool used for plotting race tactics. "We came across examples of these kinds of previsualizations that real racecar drivers use to plot their races,"

noted Darren Cranford. "They use a lot of wind-tunnel simulations and such, which we up-scaled for playback on set, but not to the point where they were unbelievable. The real racecar simulations weren't far off what we were using to plan shots for our movie. The technology these guys use for their racecars is amazing." Both Pac Title and the in-house visual effects crew at The Lot executed tracking and composites of the laptop displays where playback was not possible on set. Keyframe also created high-rez racecar graphics, which Pac Title composited to appear as a giant video wall display behind a party scene.

"Every time we turned around there were new effects to do," observed Brain Jennings. "The test screening really opened floodgates of ideas. The first thing that the audience said they liked was the girls, the second thing was the crashes; so we took another pass through the movie and Renny pushed us to embellish everything we had, adding shots to keep refreshing the effects. That was one of the benefits of shooting half a million feet of film, and covering Colin Chilvers' crashes with seven or eight cameras. We never really had to look too far to find good footage. Renny himself said that he wanted to bring the audience a new experience of racing- a raw, rock-and-roll kind of experience- and keep it very fast. I can't help but think that audiences will agree he succeeded."

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MORE WAR

image

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Sixty years after the event, Pearl Harbor re-creates Japan's infamous surprise attack on the United States Pacific Fleet in Hawaii. Though earlier Hollywood dramatizations of World War II – from the period to date – had been limited in scale by the need to utilize mockups and miniatures to depict wartime action, Pearl Harbor took full advantage of the latest digital tools to create sweeping wide views of the historical confrontation.



Director Michael Bay on the set. With broad cooperation from the Pentagon, Bay and producer Jerry Bruckheimer joined forces to bring Pearl Harbor to the screen.

As 1941 drew to a close, World War II was already more than two years old. Great Britain was reeling from massive bombing raids by the German Luftwaffe; most of Eastern Europe, Greece and the Netherlands had fallen to the Nazis; France had signed its armistice with the Axis forces; Italy had invaded North Africa; and an increasingly militaristic Japan had launched aggressive campaigns in China and French Indochina. Yet, even in the face of these widespread hostilities, the people of the United States maintained a steadfast isolationist stance- much to the frustration of European leaders and their own President Franklin D. Roosevelt. Popular wisdom held that this war was Europe's problem, not America's.

But the nation's perspective would be altered- irrevocably, horrifically- on December 7, 1941, when Japan launched 360 warplanes from the decks of six aircraft carriers in an attack on the United States Naval Pacific Fleet, anchored in Pearl Harbor, Hawaii. The first wave of the attack came just before 8 o'clock that Sunday morning, catching the sleepy harbor unaware. Two hours later, the blue skies over Oahu were black with smoke, and the Pacific Fleet was shattered.

Twenty-one ships had suffered devastating damage, and five battleships- the pride of the U.S. Navy- had sunk to the muddy bottom of the harbor. In addition, nearly 350 military aircraft- most still parked on the tarmac- had been destroyed. Most horrifying was the loss of life - 2403 American servicemen and civilians were dead, nearly half casualties of the bombing and subsequent sinking of the USS Arizona. This unprecedented, heretofore unthinkable surprise attack on the United States signified the end of America's apathy and its innocence, propelling the 'sleeping giant' into a bloody war with Japan and into the middle of the ongoing conflict in Europe.

The attack on Pearl Harbor has been the subject of relatively few movies, especially in light of the event's historical significance, its inherently dramatic elements of surprise and tragic consequences, and the popularity of World War II in general as a cinematic setting. Throughout the 1940s, when World War II-related movies dominated the silver screen, only the aftermath of Pearl Harbor's destruction was used in storylines- the battle itself was never shown. Even the Hawaii-set 1953 classic, *From Here to Eternity*, featured only a few minutes of the attack- and that came at the film's finale.



While much of the story involves a love triangle between Army Air Corps buddies Rafe McCawley and Danny Walker and Navy nurse Evelyn Johnson, the attack on Pearl Harbor consumes nearly forty-five minutes of the three-hour-long movie. The centerpiece sequence was realized primarily through the integration of full-size practical effects orchestrated by special effects supervisor John Frazier and by scale-enhancing visual effects created by Industrial Light & Magic, under the direction of Eric Brevig. Brevig reviews images from the film at a computer workstation.

Not until 1970 was the event dramatized for the screen in any significant way. That year, Twentieth Century Fox released *Tora! Tora! Tora!*, an ambitious, spectacularly staged, detailed movie re-creation of the attack. Though special effects veterans A.D. Flowers and L.B. Abbott—who earned Academy Awards for their achievement—attempted to broaden the scope of the movie by using large-scale miniatures, full-size mockups, and real Navy ships and aircraft, the physical realities of shooting practical, live elements dictated that the drama unfold primarily in close and medium shots, without panoramic, grand-scale views of the action.

Pearl Harbor would be bound by no such physical limitations. Written by Academy Award-winner Randall Wallace, the project was still titled *Tennessee* when Jerry Bruckheimer and Michael Bay signed on to produce and direct, respectively. The storyline follows two young men, Rafe McCawley (Ben Affleck) and Danny Walker (Josh Hartnett), best friends whose boyhood dreams of becoming fighter pilots are realized when they join the U.S. Army Air Corps. Rafe's decision to leave the relative safety of stateside service and volunteer for the Eagle Squadron—a Royal Air Force fighter wing comprised of American pilots defending Britain against almost daily bombardment by the Germans—does not sit well either with his girlfriend, Evelyn Johnson (Kate Beckinsale), an Army nurse, or Danny, both of whom are soon transferred to tranquil Pearl Harbor.

When Rafe's Spitfire is shot down over the English Channel, and the young pilot is presumed dead, Danny and Evelyn turn to each other for comfort. But the young lovers are thrown into a turmoil of divided loyalties and guilt when Rafe appears in Hawaii, still very much alive. In the early-morning aftermath of a bitter brawl between the two estranged friends, Pearl Harbor is attacked; and in true Hollywood fashion, Rafe and Danny put aside their hostilities and take to the air together to defend the harbor against the Japanese.

Planning to shoot their war epic on location in Oahu, in the Fox Studios Baja tank in Mexico, and on stages and locations in Los Angeles, Michael Bay and Jerry Bruckheimer turned to a variety of sources to produce the required high-octane action sequences. Visual effects supervisor Eric Brevig and his team at Industrial Light & Magic would provide panoramic battle views through computer generated effects and miniatures, while special effects supervisor John Frazier would orchestrate on-deck explosions, machine gun strafing, practical ship sinkings, and hundreds of fire and smoke effects. Stan Winston Studio would turn actor Jon Voight into a Franklin D. Roosevelt look-alike with skillfully applied makeup prosthetics, and also create hundreds of makeup effects to provide the show with graphically realized casualties of the Pearl Harbor assault.

Though the effects assignment would include air battles over Britain and the climactic Doolittle raid on Tokyo, the attack on Pearl Harbor would comprise most of ILM's 200-plus shot load. "Two-thirds of the total work we did was for the actual attack on Pearl Harbor," explained Brevig, who also served as the production's second unit director. "That is the centerpiece of the film. The sequence starts with the pre-attack as the Japanese planes fly in, then goes through the attack itself—with the bombing and sinking of the ships and the attacks on the various airfields—and ends with the aftermath, hours later, where we see the crippled warships and

Admiral Kimmel in a launch, surveying the damage. From pre-attack to the end of the aftermath is about forty-five minutes.”

Prior to shooting in Hawaii, Bay sought to divide the forty-five-minute spectacle into elements that could be obtained live, and those that would have to be achieved through visual effects. “In some cases,” noted Brevig, “it was clear what we were going to need in terms of computer generated and visual effects. For example, the production had nine practical Japanese planes to use in filming. They had one authentic Zero fighter plane– the only existing Zero in the world, which they procured from an air museum. They also had some replica Kates, the torpedo planes, and some replica Vals, the bombers, all of which had been used in air shows. So we had those nine airplanes– but we knew we were going to need about 180 planes in the movie. It was clear that we’d have to create the rest of the Japanese air fleet synthetically.” Production also had at its disposal a limited number of real P-40s– the hero airplanes Rafe, Danny and the other American pilots fly in the course of the picture. However, shots revealing vast numbers of the planes sitting on airfields would require digital replication, as would scenes– deemed too dangerous to realize with an aerial stunt crew– in which the pilots engage in games of airborne ‘chicken’ and perform other high-risk maneuvers.

ILM faced a similar situation with the battleships, cruisers and destroyers that would make up the Pacific Fleet moored in Pearl Harbor in that very few real ships were available for filming. “We didn’t know, going in, how many ships we’d need just to fill out Pearl Harbor,” observed Brevig, “but we did know that no real period battleships were available. There are only a few of them scattered throughout the country, in museum status. And there is the USS Missouri, which is anchored at Pearl Harbor, but facing the wrong way– so we couldn’t use that for anything where we were seeing it from the air. We knew we were going to have to produce battleships, one way or another.”

To demonstrate that computer generating dynamic and believable plane footage was a feasible approach, ILM produced a number of test shots, the first of which illustrated CG aircraft engaged in dogfight-style action. “The goal of that initial test,” noted sequence supervisor Steve Braggs, “was to show Michael Bay that we could create a photorealistic plane that was indistinguishable from the real thing. We looked at some World War II footage of a plane being attacked, shot from another plane’s point of view, with tracers shooting out and smoke trailing behind, the plane



Early in the picture, Rafe volunteers for combat as part of a squadron of American pilots helping the Royal Air Force defend England against German air raids. In shots of the unit taking to the skies, ILM supplemented the few replica Spitfires available to the production with digital aircraft, compositing them into aerial photography of the English landscape or backgrounds tiled together from stills.



Rafe engages a German Messerschmitt over the English Channel. Flying replicas of the World War II-era planes performed the dogfight action on location. ILM added a digital strafing effect on the water. For aerial combat shots deemed too dangerous to be performed by real aircraft, ILM computer generated one or both planes. An exact

bursting into flames and plummeting into the ocean. We re-created that for our test, since it combined a lot of the types of things we would have to do for this show. Simon Cheung built the model- one of the Japanese Zeroes- Hayden Landis developed a 'gunfire' tool for it, Scott Benza animated it, and Tony Sommers did the Viewpaint on it. When we showed the test to Michael Bay, he was very happy with the way the planes held up."

match between CG and practical airplanes was essential since many shots would feature both flying side by side.

Satisfied that he would not have to rely entirely on practical miniatures or full-size setups, Bay proceeded to design effects shots through animatics produced by Dream Quest Images and ILM. Dream Quest- which merged with Disney's animation arm to become The Secret Lab in the course of Pearl Harbor's preproduction- was initially planning to take on about half of the show's effects slate, which, at that time, numbered more than 400 shots, with ILM picking up the other half.

From the outset of the previz assignment, Bay's intention was to work out the design of shots in the animatics, then translate them essentially intact to the final shots. With all of those vital creative decisions- such as camera angle, movement, speed and overall composition- made up front, during the animatics stage, each shot would be more or less locked before shooting even began, eliminating the time-consuming and costly filming of unnecessary elements. "Michael was using the animatics as a way to make this an extremely efficient process," observed Dream Quest previsualization supervisor Richard Hoover. "By going that route, he was allowed the creative freedom to work out his shots, without spending a great deal of money. Then, when he did shoot, that process would be much more efficient, both in terms of time and money."

Nearly a year prior to the start of filming, Hoover met with Bay in Hawaii to take photographs that would be used to build virtual sets for the animatics. Upon his return to the mainland, Hoover and a team of four animators set up a network at Bay's office in Los Angeles that enabled them to collaborate directly with the director. "That effort went on for several months," explained Hoover, "with Michael directing us, hands-on. Then, back at Dream Quest, and later at The Secret Lab, we built ships and planes and additional environments for the animatics, utilizing Maya." Hoover based the animatics in real space, employing U.S. Geological Survey data of Oahu and scale-accurate maps of Pearl Harbor and Ford Island, where the military installation was situated. "Between that information and the photos I had taken during scouting, we were able to produce a fairly accurate representation of Pearl Harbor for the animatics. So when planes were flying or cameras were moving, we could get real information to pass on to all the departments- things like how fast the planes were flying, how far above the water the camera was, how far it moved. All of that information would help execute the movie."

Throughout, Bay's principal mandate was that shot designs be historically accurate in their depiction of the Pearl Harbor attack. Personnel in Jerry Bruckheimer's office had conducted exhaustive research, culling together as much movie footage, videotape, news footage and photographs of Pearl Harbor as were available. Bay also did a great deal of research, including interviewing survivors of the attack. "It was a very collaborative process," noted Hoover, "with everyone pooling their resources and exchanging tapes. All of that research greatly influenced how we designed these shots." The final animatics were fairly elaborate, featuring 3D

animation, accurate lighting, particle effects for the explosions, a color differential between land and water, and animated pilot figures visible inside the cockpits of aerodynamically-correct planes.

When budgetary realities resulted in a paring down of shots, Dream Quest bowed out of the production, leaving all of the remaining 140 shots slated at that time to ILM, which subsequently stepped up its own production of animatics and conceptual art. “We started in December 1999,” recalled ILM visual effects art director Alex Jaeger, “about three months before the start of principal photography. We had already done some animatics for the Tokyo raid and for the British air battles, while the animatics crew in Los Angeles was working on the Pearl Harbor attack. At this point, Michael started giving us the animatics that had been done down in L.A., saying, ‘Okay, here’s the basis of this shot- now let’s see what you guys can come up with.’ Some of the original animatics didn’t change much, and others changed dramatically. Overall, these animatics were used as a visual reference for placement and movement- ‘The plane enters frame from this side, does this move, then moves out.’ They were a way to quickly illustrate the idea of a particular shot.” Jaeger created the animatics on a Macintosh, building plane and ship models in Form Z, and using Electric Image software for animation.



An aerial view establishes the period location as a ferry transports Evelyn and her fellow Navy nurses to their new station at Pearl Harbor. With the exception of the harbor setting and the ferry, everything in the shot was computer generated. The production spent six weeks in Oahu filming live-action scenes and helicopter plates- shot by director of aerial photography David Nowell- which served as backgrounds for the ILM visual effects. To afford flexibility in creating those shots, Eric Brevig and co-supervisor Ed Hirsh also photographed location stills, which were subsequently tiled together to produce backgrounds into which any virtual camera move could be introduced. Modern-day buildings and architectural features inappropriate to the era were painted out of both plate and still photography.

Just as Dream Quest had done, the ILM animatics team would rely on reference footage to guide it in the design of the shots. Of particular interest was a recently released DVD, *World War II in Color*, which- as its title suggested- offered rare color film footage of World War II action, such as dogfights, ground battles and bomb explosions. "We must have watched that thing a hundred thousand times," said Jaeger. "Michael Bay was very adamant that we use that for guidance. We also looked at all of the real newsreel footage from Pearl Harbor. Michael wanted to make sure everything was right- or as right as it could be."

Armed with more than a hundred animatics, Bay, Brevig and their crews arrived in Oahu, in March 2000, with a solid understanding of what background and other live-action elements would have to be captured in order to fulfill the shot designs. The production left Hawaii six weeks later to shoot non-effects-related scenes on stage and on locations in Los Angeles, then moved on to

the Fox Studios Baja tank for the filming of large-scale special effects gags such as the sinking of the *Oklahoma*. Other scenes and effects shots were realized on the battleship *USS Texas* in Houston, and on the *Lexington*, a vintage aircraft carrier moored in Corpus Christi. Much of the spectacle that might have been relegated to the visual effects unit was captured in-camera in the course of these excursions. "As a shooting unit," commented Brevig, "we were able to film, in-camera, many of the events that no one thought we could do. Because of that, postproduction enhancement for many shots was not necessary. The only things we couldn't film live were the dangerous and grand-scale shots; so the visual effects effort became creating visual spectacle on a scale that was impossible to do practically, or was too unsafe to attempt."

Animation would be done in Alias/Wavefront's Maya, necessitating a major reworking of ILM's traditional pipeline, a task led by Craig Hammack. A plug-in developed by Pixar- named 'M-tor,' for Maya-to-RenderMan- was used on a small number of shots to allow for RenderMan rendering directly out of Maya. "We kept to our standard pipeline for our hero shots," recalled sequence supervisor Joel Aron, "because those shots were extremely dependent on the tools that we have written to make them absolutely believable. But for other shots, M-tor allowed us to put out shots fully within Maya, without going outside of that program. So what might normally take months to do- animating, lighting and rendering a shot- we could do in a week and go straight to film. To be able to stay in one package for an entire shot was fantastic."

One of the film's earliest visual effects shots involving Pearl Harbor is an establishing view of the area some months before the attack, as Evelyn and her fellow Navy nurses arrive by ferry. "In this shot," stated sequence supervisor David Horsley, "you can see Pearl Harbor in all its



An aerial view establishes the period location as a ferry transports Evelyn and her fellow Navy nurses to their new station at Pearl Harbor. With the exception of the harbor setting and the ferry, everything in the shot was computer generated. The production spent six weeks in Oahu filming live-action scenes and helicopter plates- shot by director of aerial photography David Nowell- which served as backgrounds for the ILM visual effects. To afford flexibility in creating those shots, Eric Brevig and co-supervisor Ed Hirsh also photographed location stills, which were subsequently tiled together to produce backgrounds into which any virtual camera move could be introduced. Modern-day buildings and architectural features inappropriate to the era were painted out of both plate and still photography.

glory. You see forty ships- some cruisers, some battleships, some destroyers, and one aircraft carrier. But the only thing actually shot for that was the harbor and the ferry. All of the ships were computer generated."

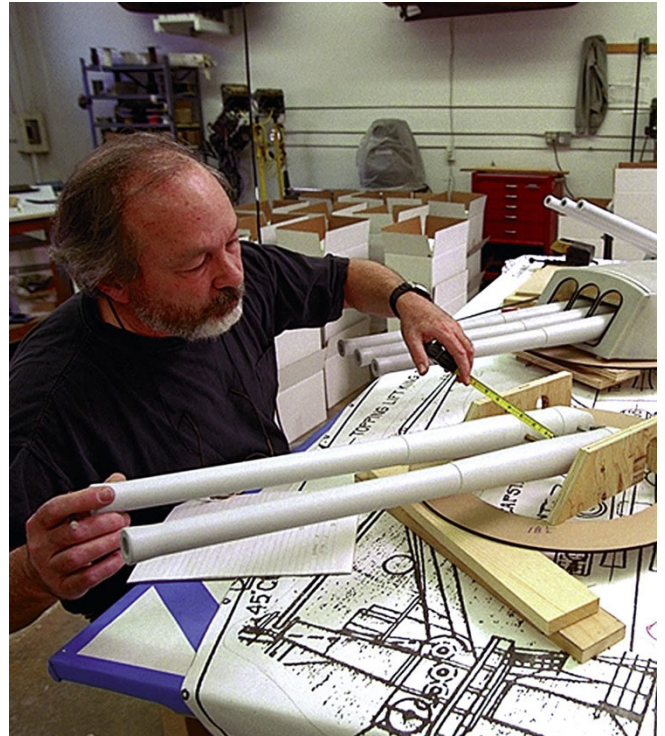
Aerial director of photography David Nowell filmed the live- action plates for this and all of the Hawaii backgrounds from a helicopter, with either Brevig or co-supervisor Ed Hirsh on board to supervise the plate photography. In addition to the motion picture plates, Brevig arranged for still photographs of Pearl Harbor to be taken, which would be used to tile together backgrounds, as needed. The advantage of a tiled background was its flexibility- unlike an aerial plate featuring a fixed camera movement, any virtual camera move could be applied to a tiled background. "We'd do a best-guess motion picture plate," said Brevig. "Then I'd ask Ed Hirsh to shoot these tiles; and invariably, that's what we went with for our backgrounds. It just gave us more freedom to design the shots in post."

Both the moving and still background images needed to be tweaked considerably to reconfigure modern-day Pearl Harbor into its 1940s counterpart. "There was a lot of work just making Pearl Harbor look the right period," Brevig recalled. "The existing Pearl Harbor is nicely developed now, of course. There are high-rises on the nearby hills, and the memorial at the site of the Arizona's sinking. There is a bridge that connects Ford Island to the rest of Oahu, which wasn't there at the time. So we had to paint out a lot of those anachronisms." Out of respect for the Arizona memorial, the production decided to move the location of battleship row about a quarter mile to the south of its real-life position, placing markers in the water to designate the positions of the battleships. The production also filmed on-board explosions and other shots in an adjacent harbor where a mothball fleet of inactive ships was anchored- some of them actually from the correct period. "But those frequently had to be replaced or worked on because they've been refitted dozens of times since then, with radar and things like that added. So we had to replace the tops of even real period ships with matte paintings or just digitally remove anachronisms and replace them with something appropriate."

The establishing shot of the ferry and harbor reveals battleship row, where the Arizona, Nevada, Oklahoma, West Virginia, California, Tennessee, Maryland, and the supply ship Vestal, were anchored at the time of the attack on Pearl Harbor. At the beginning of the project, there was much debate as to whether CG battleships or miniatures would ultimately prove to be the more useful- though Brevig initially leaned toward the latter. "I had real concerns about CG battleships at the start," Brevig admitted. "These ships were going to be very complicated, very detailed, very huge and potentially very close to camera- and we just didn't know how far we could go with computer generated versions. All of that made me think, initially, we might be way ahead going with a miniature."



Among the effects team's principal challenges was creating a highly detailed CG battleship that could be modified to represent any of the vessels anchored in the harbor. To keep his options open as ILM explored the feasibility of an all-digital approach, Bay had the model shop build a 1/20-scale ship- ultimately relegated to backgrounds when the CG version proved successful. Modelmakers Dave Fogler and Mike Jobe drape the hull of the miniature in preparation for painting.



Modelmaker Charlie Bailey works on gun turret prototypes for the battleship. Interchangeable turrets and other features were built so that the model- a replica of the USS Oklahoma- could stand in for a variety of ships.



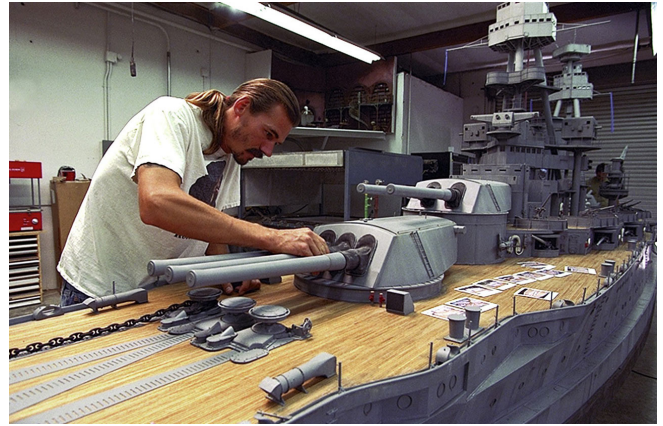
Two miles of real teak planking went into the authentically crafted wood deck. Modelmaker Chris Reed trims the deck prior to fitting.

To determine the viability of computer generating the battleships, Brevig proposed that a test shot be put through the pipe-line. "What Eric wanted to determine with this test was, 'Can we really make a CG model that's more realistic than anything we've seen before?'" recalled associate visual effects supervisor Ben Snow. "The idea was to proceed with this test, see where we were in a month, then make the final decision as to whether to go with CG or a miniature."

The battleships broke down into two essential types- tripod-tower ships and lattice-tower ships. Modeling supervisor Peter Bakic built a model based on the former style, which would be used to represent the Arizona, Nevada and Oklahoma. A modified version of that model was employed for the lattice-tower ships, which included the West Virginia, Tennessee and Maryland. "The differences between the two types of ship were mainly in the towers," explained Viewpaint lead Ron Woodall, who also had a hand in the modeling of the CG battleships, "but there were other differences here and there, such as the gun turrets. I took the original ship that Peter had modeled and modified it to make the lattice-tower ships. Then we did various paint schemes to make these two basic models look like eight different battleships."

The paint schemes, done by hand, were derived from photographic references, but deviated from the historical record. "In reality," observed Woodall, "all of the ships at Pearl would have been gray-on-gray, because that was a non-wartime color. But we painted all of them except the West Virginia blue-on-blue - which was incorrect, but what Michael Bay wanted." The gray coloring on the West Virginia was meant to match live-action footage photographed on the gray Missouri, which stood in for the doomed West Virginia in scenes aboard that ship involving mess attendant Dorie Miller (Cuba Gooding, Jr.), the first black American to receive the Navy Cross, awarded for bravery during the attack on Pearl Harbor. "They wanted that one ship to be gray so that it would look like the same boat you see his character on in closeups."

With the exception of the dramatic license taken with the color of the ships, the CG modelers and Viewpainters endeavored to make the battleships as accurate as possible. "That was very important," stated Woodall. "We all wanted to make sure that we brought an accurate representation of what actually happened to the big screen. There was one point, in fact, where we were discussing not modeling the Vestal, which was a supply ship, and replacing it with a destroyer. But I argued against it. I didn't want those guys that were on the Vestal to come see



Lead modelmaker Bryan Dewe details the battleship, which measured thirty feet long.



Modelmaker Brian Gernand paints the vessel, redressed as the USS Arizona. The upturned model was photographed outdoors to provide lighting reference for computer generated shots of the doomed battleship.

this movie, and say, 'Hey, where's my boat?' So I got Bruce Holcomb to model that ship, and I painted it."

A key issue to be resolved in the CG battleship test was lighting. The traditional technique of surface-lighting digital models by placing virtual lights one by one, based on reference from location, was not going to suffice for these shots, given their complexity, their length and their proximity to camera. Radiosity- which results in a more realistic lighting effect, with every surface interacting with every other surface- was also not an option. "Radiosity was too render-intensive," noted Snow, "but something like radiosity was going to be necessary to get the level of realism we needed in the battleships. So we began to work on ways to actually 'bake' the radiosity in- precalculate it and then reuse it for shot after shot. Since these battleships don't really move, we could do it once for a shot, and then use it for all the other shots. We had technical director Ken McGaugh do tests of that."

Still uncertain as to the ultimate success of those tests, Bay commissioned ILM to build a battleship miniature. Model shop supervisor Michael Lynch and his crew began constructing the 1/20-scale, thirty-foot-long battleship miniature- a replica of the USS Oklahoma- from declassified blueprints procured from the Navy. "They were the same plans that had been used originally to build that ship," recalled Lynch, "dated 1912 or something like that, when it had first been commissioned.

Working from the exact blueprints was interesting, and it allowed us to build a very accurate rendition of it. We deviated from history somewhat, because that one miniature was originally going to represent five other ships on battleship row. It was historically accurate as the Oklahoma; but if we were using it for the West Virginia, for example, it wouldn't be. To correct that, we made a lot of interchangeable parts- turrets, masts, catapults and so forth- which we could switch out quickly to change the model from one ship to another."

The modelmakers followed the same basic procedures used in the building of full-size ships, with bulkheads clad in plywood to produce the hull. "This miniature had to hold up within a couple of feet of the camera," observed Lynch, "so we went to a lot of trouble to get every detail right. For example, the real ships had teak decking because teak oil shed water and was a bit



Battleship row at Pearl Harbor, prior to the attack. The two foremost ships and the dock were filmed in an adjacent harbor where the Navy mothball fleet was moored. Modern equipment visible on the deactivated ships, such as radar units, was digitally removed. CG battleships filled out the background.



Transported by ship to within striking distance of Pearl Harbor, Japanese planes prepare to take off from an aircraft carrier. The USS Lexington- a real American carrier moored in Corpus Christi- stood in for the Japanese ship during the live-action filming. ILM digitally reconfigured the American vessel to make it more closely resemble its World War II-era Japanese counterpart, added computer generated Zeroes to fill out a handful of replica planes, and removed Corpus Christi in the background, replacing it with an ocean view.

sticky, which helped to keep people from slipping. So we made our miniature decks out of real teak veneer planks, laser-cut to 3/16ths of an inch wide. We ended up using two miles of that planking to get the whole ship done.”

As Lynch and his crew progressed with the miniature, the CG battleship test began to show promise. “We’d kept working on the CG ship,” related Ben Snow, “and kept working the lighting problem. Eventually, sequence supervisor Hayden Landis spearheaded a way of using reflection maps to light a scene. Usually on our productions we shoot chrome and gray sphere reference of each shot, and then we’re able to use that as reflection-map reference. In the last few years, we’ve been looking at ways of using that information for lighting, as well, essentially making a big map of the chrome sphere in the sky. The problem we have always had with using that to create light is that it reflects light on every surface, without taking occlusion into account. So, say you have a ship with a tower right next to it- the sky that’s on the other side of that tower would still be illuminating the ship, even though it should be shadowed by the tower. It didn’t account for those types of interceptions of the light. But during the research and development phase of this show, Hilmar Koch, Hayden Landis and Ken McGaugh really cracked that problem. They came up with a solution that involved a ray-trace pass, and then storing the information calculated from that in such a way that when we were doing our render it could say, ‘Okay, I’ll have a look at this map that we’ve stored previously.’ And that map would tell where it needed to be shadowed, how much it should be shadowed and so on.”

As a result of the new lighting technique, the CG battleship looked completely convincing and stood up even in extremely close-to-camera shots. “The success of the test shot freed up my thinking for all of the battleship shots,” commented Eric Brevig. “Even though I had thought we would have to use the miniature for many of them, there had been a lot of problems connected to that approach. It would have meant some very difficult tracking, for one thing, to get this big ship into our background plates.” A CGship would also free the effects team from the difficult chore of tracking computer generated characters into the miniature. “We had shots requiring hundreds of people on board these ships running for cover, grabbing guns, jumping into the water and so forth- and although we’d had extras and stunt people on location to do some of that stuff, we knew that we’d be adding a lot of CG people. And I’d always felt that integrating CG people onto a miniature ship was problematic. They did it on Titanic- filmed a miniature, composited CG people onto it, tracked them and tracked the miniature, then matted them behind everything that crossed their paths- but I thought, ‘Boy, that’s a lot of effort; and when you’re done, it doesn’t look like you’ve done that much.’ I thought that if we could just get our CG ship and put our CG people on it, they could cast shadows on each other, and one would always know where the other was. It would be a real economy of effort, and we could spend our time making them look really good.”

The final decision was to proceed with both the digital battleship model and the miniature, using the former for foreground ships and the latter for backgrounds. Though the miniature was not in a large enough scale to do convincing explosions on it, it was very useful for interactive shots of black smoke curling around ship towers- shots that would have been very render-intensive to do with particle smoke. The battleship miniature was shot on the ILM backlot, on a 150-foot-square concrete slab poured specifically for the Pearl Harbor model

shoot. Miniature pyrotechnician Geoff Heron created the interactive smoke. "We used a naphthalene-based smoke that looked really black and billowy when shot at 120 frames per second," stated Heron. "I thought it was pushing it to try to make 1/20-scale smoke look good- but it did. We filmed both stand-alone smoke elements and smoke that was plumbed into the battleship, with smoke pots jammed in the cabins and other areas, being careful not to burn up this expensive model."

When the decision to utilize CG ships in the foreground relegated the miniature to background status, Michael Bay came up with another use for the model- a modern-day view of the sunken, barnacle-encrusted Arizona sitting on the harbor floor. "We transformed our 1/20-scale Oklahoma into the Arizona as it looks today," Lynch elaborated. "We had to take a chainsaw to the model, and cut a huge gaping hole in it. By the time that bomb ripped apart the magazine of the Arizona, there wasn't a lot left of the deck that was recognizable; so it wasn't too hard to transform it into the Arizona for this sequence." The revised model was photographed dry-for-wet, in smoke, with CG particles enhancing the underwater illusion. "It hurt to destroy that model- but production had paid for it, so they had to use it as much as possible. Michael Bay wasn't interested in souvenirs. He wanted the best movie he could get."

In a prelude to the Pearl Harbor attack, the film cuts to a shot of an ocean-bound fleet of Japanese warships- including aircraft carriers on which the Zeroes, Kates and Vals are parked- steaming its way towards Oahu. An annual meeting of the Pacific Rim Fleet in Pearl Harbor provided the view of the Japanese ships. The official gathering had dictated a hard-exit date for the production - which left Hawaii in late spring 2000- but it afforded an opportunity to capture a tremendously useful live-action plate. "There was a gathering of thirty-some ships traveling towards Hawaii," Brevig commented. "Dave Nowell and I got clearance to shoot it from a helicopter about seventy miles off the coast. Later, we doctored that footage, and it became the Japanese fleet steaming toward Pearl Harbor. We also used it for shots of the aircraft carriers you see prior to the Doolittle raid. It was a great opportunity for us." Viewpainter Scott Bonnenfant painted the ships to look like period Japanese aircraft carriers, with minimal detail required since their



Boy Scouts on a wilderness excursion witness Japanese Zeroes, Vals and Kates - attack planes, bombers and torpedo planes, respectively- flying through an island valley. Background plates shot on location featured two real planes at the head. All the rest were computer generated. The light weight and relatively slow speed of the vintage prop planes made it necessary for animators to introduce a slight in-flight wobble to replicate the effects of wind buffeting.



Having fallen asleep in a parked car across the harbor, Rafe and Danny awoken to discover Japanese warplanes passing overhead, flying toward battleship row. ILM composited synthetic planes, battleships and a painting of the far side of The Island into the live plate.

early morning approach is seen from a long distance. Closer views of the Japanese readying for their mission on the decks of the ships were shot on the real carrier in Corpus Christi.

The Pearl Harbor attack sequence begins with shots of Japanese planes flying low over The Island. The show's aircraft were among Michael Bay's principal concerns from the beginning of the project, since synthetic planes would be flying alongside real ones throughout the film- and, in some cases, one would replace the other in mid-cut. Such proximity would require that the CG planes match the real ones perfectly; but, to Bay's mind, a CG plane that was truly indistinguishable from the real thing had never been achieved.

One of the early projects taken on by Hayden Landis was the realization of an ultrarealistic CG plane, a task that benefited tremendously from the global illumination lighting technique first developed for the virtual battleships. "The new approach for creating ambient light environments gave us really realistic lighting on the planes," Landis related. "Usually, you fill-light an object by throwing a bunch of lights at it. That takes a lot of time and can be very computer-intensive; and you are still only taking your best guess at what that entire light environment is. With this new technique, we used the chrome sphere references we had shot on location to give us completely accurate direction and color for all the fill light around the object, as well as an accurate reflection on it. It killed two birds with one stone. The sphere would record the environment; then we could take those images, 'unwrap' them into a map, and surround our CG models with that map. Many times, we could just drop in this ambient environment light information, and it was like, 'Wow, that works,' right off the bat."

As with the CG battleships, occlusion maps determined the amount of ambient light falling on given areas of the model. Whereas part of the engine might 'see' only five percent of the outside light, for instance, the top of a wing would 'see' ninety percent. "We'd run a ray-trace Mental Ray shader, which computed, for every point on the object, how much light it should see," explained Landis. "It was a kind of 'faux radiosity.' It gave us ninety percent of the radiosity look, but with a fraction of the computation necessary."

An expedient texture-mapping technique also facilitated the creation of CG planes.

"Stereotypically," said Ron Woodall, "we get photographs of the real objects we're computer generating from someone on the set- a production assistant or someone like that. And, usually, they have a crummy camera and they take awful pictures that are not at an angle that can really be directly applied to a CG model. But when we started this show, everyone knew that the CG planes would have to match the real planes exactly. Tony Sommers, model shop veteran turned Viewpainter, had this awesome idea of taking beauty photos of the real planes and applying the images directly to the models. He, Sean Casey, ILM's still photographer, and I went to Hawaii for five days. We carefully shot each plane from every axis needed to cover the CG models. We had a forklift to raise the tail of the plane so that its centerline was parallel with the camera's horizontal plane. A large crane was used to lift each plane thirty feet in the air so Sean could take pictures of the underside, as well. We had a great troupe of grips and plane wranglers who feverishly changed lighting schemes and plane positions with dogged dedication- even though I know they were thinking, 'What the hell are these guys doing?' We then returned to ILM, where the photos were scanned and applied to the models by Tony, Scott Bonnenfant and myself. The end result of all that work was invisible, in that you cannot tell the

difference between a real plane and a CG plane. We even fooled the director on more than one occasion.”

The CG plane models not only had to look exactly like their real-life counterparts, their movement had to be indistinguishable as well. “One of the most challenging aspects of the show,” noted Ed Hirsh, “was animating the digital planes so that they looked absolutely real. We had a lot of reference footage of the vintage planes flying in Hawaii, and we looked at that to study their movement- the subtle little corrections they made, how they looked when they made turns, et cetera. Everybody knows, instinctively, what a plane in flight looks like. You may not be able to verbalize it, but you can sure tell when it’s wrong. So we would look at our animation, and say, ‘Well, that doesn’t quite feel heavy enough.’ Or, ‘It’s going too slow.’ Or, ‘It’s wiggling too much,’ or ‘It’s not wiggling enough.’ In some ways, it was more difficult to animate these propeller-driven aircraft than a jet because they were moving so much more slowly.”

“There is a big difference between the speed of a World War II plane and today’s fighter jets,” commented Scott Benza, who was the lead animator overseeing how the digital hard-surface models would interact and fly. “They are much lighter, smaller and slower; so they get pushed around by the wind a lot more, whereas a fighter jet would just carve through the air. We had to take into consideration how the plane would be navigated, as well as how the wind would affect what the pilot was trying to do with the plane.” Early on, there had been some thought of developing a wind simulation that would create this buffeting effect on the airplane. “But we found that by just looking at the reference and relying on the animators’ abilities, we could simulate all of that and have much more control over it.”

Craig Hammack, with contributions from James Tooley, wrote additional tools that could be plugged into the basic Maya animation package. One such tool enabled animators to animate the plane in real-world, miles-per-hour values. “We could tell Maya that we wanted this plane to fly 250 miles per hour,” said Benza, “and the plane would actually fly 250 miles per hour in the shot. We also had a tool that allowed us to, with a press of a button, animate the control surfaces based on the actions the animator had defined for the plane. So if the animator wanted the plane to roll over, he would press a button and the ailerons would automatically turn— just as they would on a real plane. It was the reverse of what happens in reality: in the real world, if you turn the flaps, the plane rolls. But for our animation, we would roll the plane and the computer would know to initiate the turning of the flaps about ten frames ahead.”

One of the shots of the low-flying Japanese planes is seen from the point of view of Rafe and Danny, who are sleeping off a drunken brawl in Danny’s car, parked in a remote part of The Island. Synthetic airplanes, rendered by Kathleen Davidson, can be seen flying over the characters, then out over the harbor, all with the appropriate shadow interaction and reflections in the water. “In the plate,” related compositing supervisor Marshall Krasser, “there was nothing but ocean as far as the eye could see. We had to get rid of the wave breaks and put in a matte painting of the far side of The Island. We also had to add the sleeping fleet of warships,



John Frazier and his team rigged numerous practical explosions on the mothball fleet in Hawaii to simulate the destruction of ships as the Japanese planes drop their payloads. Frazier also built a system of air valves underwater to simulate the effect of strafing runs, and set off dynamite in the harbor to produce giant plumes of water, representing bomb detonations. ILM enhanced the real explosions with CG debris, and added synthetic airplanes to the shot.



For a fly-through shot of Pearl Harbor under attack, digital ships, planes, smoke and fire elements were composited into an empty aerial plate of the modern-day harbor. Although Frazier produced some smoke on location, environmental and safety issues precluded him from duplicating the billowing black clouds of it seen in historical photographs of the Pearl Harbor attack. ILM created huge volumes of such smoke using a new dynamic simulation technique.

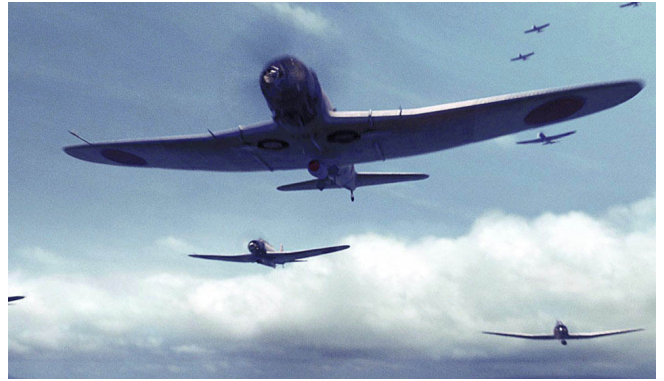
rendered by Mike Halsted. It's another shot in which, if we did our job right, no one will ever know that there was nothing there but ocean in the live plate."

In another early shot- featured in the film's trailer- a troop of Boy Scouts on a wilderness excursion witness the arrival of the Japanese planes as they fly over the green valleys of Oahu. The shot- which featured two real aircraft and dozens of computer generated replicas- emerged early in the effects schedule, and served to lay the groundwork for the plane animation and lighting. In the compositing stage, shadows from the CG aircraft were added to the ground in the live-action plate. Digital fixes were also executed. "One of the Boy Scouts in the plate had turned to look back over his shoulder as Eric Brevig gave him direction," explained Krasser, "and it was obvious that he was looking back at the camera. So I took a frame where he was looking in the correct direction, and hand-tracked it in, effectively eliminating the head-turn. We corrected a lot of action in that way."

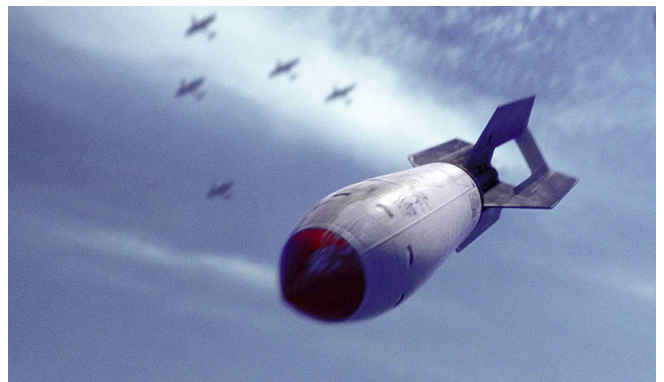
As two crewmen hang over the side of the Oklahoma, painting her hull, one of the Japanese Kates drops a torpedo, which speeds through the shallow harbor toward the ship. Some live-action for the shot was captured on the USS Texas in Houston. "The practical crew had dragged a dummy torpedo through the water," related Krasser. "Compositor Jeff Sutherland extracted the dummy's wake and bubble trail and combined it with a rendered wake and torpedo pass he had received from technical director Russell Earl. Then, when it hit, we added explosion elements from our database to the explosion that was actually shot, just to give it more detail and substance. Throughout this show, Michael Bay was always saying, 'More war- I want more war.' So we'd give it to him."

Practical explosions were rigged and filmed on the mothball fleet anchored near Pearl Harbor. Many of these ships are not on active duty but are maintained at a minimum level- a less expensive option for the Navy than decommissioning them. "John Frazier did a lot of explosions on those ships, being careful not to hurt anything," Eric Brevig recalled. "Even if a ship was there on its way to being turned into scrap, we still had to return it to its former look. We had to repaint it if any paint got singed, for example. This movie has more things blowing up than any film I've ever seen- and John Frazier engineered all of that."

Before leaving Hawaii, Frazier would simulate the destruction of seventeen ships using the mothball fleet- and never leave a mark. "We'd go into the ship and find out where the bulkheads were," recalled Fraizer, "and set up our explosions there, where the structure was the strongest. We also put trenchplate down on all the decks to soften the blow of the explosives. We did explosions on six ships at one time on one pass, using four thousand gallons of gasoline. We did explosions on five ships on another pass, the next day. And then, on various days, we blew up another six ships to total seventeen." A black smoke comprised of burning diesel fuel augmented the pyrotechnics. "We worked on getting that particular black smoke for quite some time. The problem was that we couldn't spill any of this diesel fuel- everything we did had to be contained. So we made up these burners; and then, in front of the burners, we rigged what we called 'coffins.' These were three halves of a 55-gallon drum welded together; so any excess diesel fuel that did not burn in the burners would just go in the coffin and burn off there. We put those all over the ships, and all over the harbor area. The black smoke was horrendous, but really effective- and, fortunately, the trade winds blew it away from The Island."



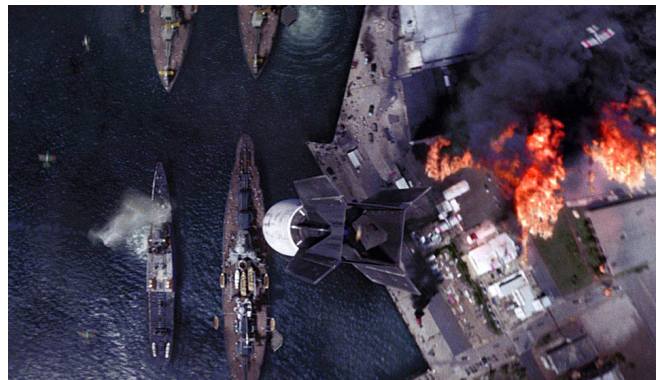
In the film's signature shot, the camera follows a bomb as it falls from a Val toward the USS Arizona, anchored below. Production had originally attempted to capture the camera move with an aerial background plate, into which ILM would composite the computer generated bomb and warships. When the live camera was unable to travel at the speed Michael Bay desired, however, ILM created a synthetic background and effected a virtual camera move, inserting digital bomb, warships, planes, crewmen, smoke, fire, sky and water. To avoid a too-perfect look to the all-CG shot, camera shake and wobble were introduced into the virtual camera move.



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In the movie, as in history, the explosion on the Oklahoma results in the ship's listing 180 degrees to the side, ending up upside-down in the water. The capsizing of the Oklahoma was Frazier's biggest, most complex gag of the show. In the forty-foot-deep section of the two-acre Baja tank, his crew fashioned a 150-foot full-scale deck set—representing the front third of the entire ship— and mounted it to a gimbal mechanism, engineered by Ross Young. “The setup was similar to holding an ice cream bar out in front of you by the stick,” Frazier commented. “That ice cream bar weighs a lot more than the stick, so we had to have counterweights cantilevered out on the gimbal arm. The gimbal, made of steel, would turn the entire ship counterclockwise until it was upside-down— up thirty degrees and over 180. The set and gimbal setup weighed 700,000 pounds, so we had to dig out the existing concrete in the tank and put in our own steel and concrete to hold it into the back of the tank.” The gimbal operated off a simple cable-and-drum system. “We mounted a motor and a winch on the back of our rig, and then wrapped one-inch-thick cable around a big drum, which was about the same size as the diameter of the ship— roughly thirty feet. So the cable went on that drum, and there were ties off at the opposite ends. One would hold it back and one would pull it. It was the same setup they used in the old soapbox derbies. It was all manual, too, except that we had monitors on it to tell us when people were on it and where, so we could make sure it never got over-weighted on one side or the other. That was the biggest safety issue, just knowing where the weight was, so this thing wouldn't get away from us. Michael would line up a shot with a certain number of guys; and we'd multiply that number of guys by about 200 pounds— the average weight for a man— and we'd say, ‘Okay, you can do that.’”

Two hundred fifty extras and stuntmen portrayed the sailors sliding on the deck of the battleship as



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it rolls over. As a safety precaution, the gimbal was engineered so it could be stopped at any point in its roll. "We actually had two braking systems," Frazier stated. "We never had to use them, but they were there, just in case." The entire 180-degree roll could be executed in approximately fifteen seconds, if needed- but, most often, Bay asked for only a few degrees of tilt at a time as he shot specific pieces of the sequence.

The roll and capsizing of the Oklahoma also required a great deal of postproduction visual effects work. As massive as the Baja rig had been, and as flawlessly as it had performed, when composited into some of these grand-scale shots, the set was dwarfed. "One hundred fifty feet sounds really big," Brevig observed, "and when we were there walking the set, we thought: 'Wow, this is great! This is really going to give us a lot of what we need.' And it looked amazing in the dailies. But it was just a fraction of what we really needed to get wide views of this six-hundred-foot-long battleship."

Technical director Aron Bonar tweaked the CG ship model to make it better match the live-action deck set. Digital water was also composited in to replace the too-calm tank water. "Michael Bay said the water in the tank looked like a lake," recalled Ben Snow. "It was much too calm and smooth, considering all the activity that was going on. So we messed it up with debris and made it more choppy. John Helms did a lot of shader work on the water, and created a very nice effect that worked well from that angle."

Computer generated people were also added, to augment the live performers in wide shots of the action. "We had pictures of the sailors in uniform they had used on the set," commented Scott Wirtz, who was the animation lead on the CG characters, "and we modeled off of those photographs. We also had some of the costumes sent to ILM; and one of the TDs stood in a good, neutral position and modeled them for us. We utilized that to sculpt eight different models. Since this one guy modeled all the different clothes, all of the CG extras had the same face, but they were so far away in the shots, you couldn't tell. We came up with different body types; and with the different clothes, it sold as different people from that distance."

To animate the digital characters, Wirtz directed two motion capture sessions, using several ILM staffers as the performers, with Doug Griffin heading up the mo-cap crew. "We put the performers in the motion capture suit and had them run around and act as if they were being shot at, and that kind of thing," said Wirtz. "We got two guys who were both about six feet tall- since they were the same size, we'd only have to write one program for putting that motion capture data onto our model. We did the first motion capture session in one day, getting about a hundred different actions. The second session took two days because it involved a stage that we could tip to different angles. Their action was to hold onto the side of this stage or roll down it as if they were on a boat that was tipping over. We also set up a railing- measured to be the same height as the railing of the ship- and had them running and jumping over that."

CG supervisor Mike Bauer took all the motion capture data and produced a library of sixty-four performances from which animators could choose. Each performance could be applied to any of the CG figures. "One performance might be a guy ducking and running," explained Bauer. "Another would be a guy leaning on a railing and talking; another would be someone falling. When applied to our six geometry types, and their five varieties of accessories, it worked out to

something like two thousand variations to choose from. Even though we would never see that many individuals in any given shot, when we had a wide shot of a ship with people all over it, it helped to have that much variety so we could make them all look different.”

For maximum efficiency, Bauer and technical director Doug Sutton developed a ‘sailor management’ tool that allowed the motion-captured performances to be plugged in as they were or tweaked through hand-animation. The interface also enabled the animators to preview the performances before adding them to a scene. “In the past,” observed Bauer, “there was no way for an animator to see what he was placing beforehand. He would pick the ‘number five’ character and the ‘number sixty-four’ performance, working from a list that assigned numbers to each character and each performance. That was tedious; and after a while, an animator would just start putting in the characters and performances he was most familiar with. So the tendency was to keep using the same dozen characters or performances over and over again, instead of the two thousand variations he had at his disposal.

“With this interface, the animator had the ability to pick one of the motion-captured performances, select the uniform type and the accessory type, then view it on a movie file so he could see what he was going to put in before he did it. The user interface wasn’t anything new– just more advanced, which made it easier for the animator to use, and made it more likely that he would use a wider variety of things.”

Even so, the animators had favorite characters and performances, which they had to refrain from overusing. “We had one sailor who was mopping,” recalled Wirtz, “and we all loved him. When we captured him, he was holding a real mop with motion capture sensors on it so that we could line up a CG mop handle to his hand. We wanted to use him all over the place, but we couldn’t because he would have stood out. None of these guys was supposed to stand out to the point that they distracted from the shots. They were just there to help bring the background to life a bit.”

Some shots would call for a background character to be cata-pulted into the air by the blast of an explosion. Wirtz produced a kind of CG crash-test dummy for such shots. “I modeled it so that if it was blown up it would react just as a human would,” explained Wirtz. “I put an explosive force on it so it would blow into the air. Normally, a model would turn into a kind of rag doll, just



In another all-CG shot, the Arizona explodes violently when the bomb plunges through its upper decks and detonates in the munitions hold. A dynamic simulation applied to a breakaway version of the CG battleship model was used to create the dramatic buckling action and subsequent disintegration of the ship. Another simulation created a percussion effect on the harbor as the ship lifts and then drops back into the water. Work on the Arizona explosion– one of the most complex shots in the movie – started on the first day of postproduction and finished just two weeks before the film’s completion.



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flopping around. But we wanted to see the arms and legs still moving in a realistic way. So I put expressions on the arms and legs that made the joints move as it flew through the air, to give it some life. I did about twenty different explosions from different angles in that way so we could have a library of these kinds of actions.”

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Although, initially, the intention had been never to place the digital characters any closer to camera than 100 feet, Michael Bay began pushing those boundaries as production continued. In one shot during the Oklahoma sequence, a digital performer is momentarily the center of the action. “He blends from a real person,” remarked Wirtz, “then falls and flips into the water. I hand-animated that one. There had been a live guy there, sliding down and waving his arms. But Michael thought he looked too happy, and so he asked us to get rid of him and replace him with this CG guy.”

For many of the high-elevation falls- which could not be motion captured- ILM utilized a technique called ‘match-mation.’ “When they were shooting in Baja,” Wirtz recalled, “Eric Brevig directed some second unit stuff of stuntmen jumping off the boat set as it tipped into the water, shooting from four different angles. Seth Rosenthal, the motion capture supervisor, developed a method to calibrate the four camera views, using tracking software developed by Steve Sullivan, so the action from all the angles and the CG models would line up. That helped us in a lot of our shots of guys falling and jumping in the water.”

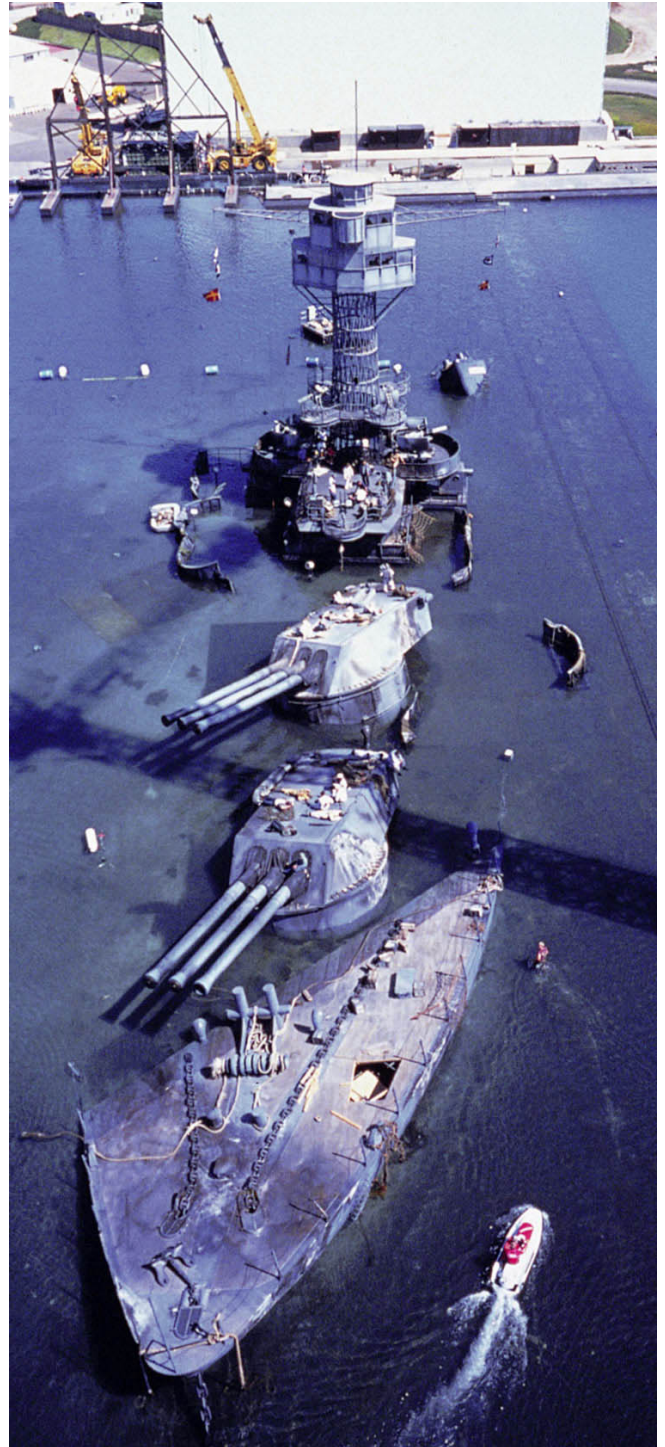
Mid- and foreground victims seen in the Oklahoma destruction and throughout the Pearl Harbor attack sequence relied on makeups and dummies provided by Stan Winston Studio. Winston supervisor John Rosengrant- an avid World War II history buff- had actively pursued the project. “I begged Stan to read the script and give us a chance to get involved with it,” Rosengrant said. “After he read the script, Stan was intrigued, as well. It just seemed like a great project to do.” Rosengrant and co-supervisor Scott Stoddard began preliminary work on the film in February 2000, just prior to the start of principal photography. “To show Michael Bay the kinds of things we could do to help sell the story, I found photographs of war victims — burns, gunshot wounds, real-life stuff — and put together a big package for him. Later, he called and said it was the most disgusting thing he’d ever seen. From that, he chose the kinds of things he wanted to see- always keeping a PG-13 rating in mind- and we made a list of what we’d have to build.”

On that list were twenty articulated stunt bodies which could be dressed up as sailors, marines, mechanics, civilians- whatever was needed- then placed next to practical explosions and fires. “These were generic bodies in various stages of injury,” commented Rosengrant. “They could be set in gun turrets or a plane. Then an explosion could go off and you’d actually see these bodies flying through the air- and since they were articulated, they would move realistically, not like limp dummies.” Body casts of Rosengrant and crew member Mark Viniello provided the basis for the stunt bodies. “Mark is about six feet, two inches, and I’m about five feet, nine inches- so we had a range of heights that we could cheat from those two basic body casts. Then we produced head casts of guys in the shop.” Jeff Edwards created an articulated aluminum frame

for each body, which provided support. “The joints could be unlocked, allowing it to be floppy and reactive with the proper hyperextensions so they wouldn’t bend back too far. They could also have their joints locked into a position, if needed.”

For some of the bodies, injuries were sculpted into the lifecast forms to suggest a variety of wounds or dismemberments, while others remained whole. “We had five or six bodies that had no bullet hits or any other kind of damage,” said Stoddard. “Those were just very realistic, intact bodies. Others were missing limbs, or had injuries sculpted into them. We’d make molds off of those sculpted lifecasts, then cast them up in silicone and urethane.”

Stoddard arrived in Hawaii with the twenty stunt bodies and a cache of makeup appliances and supplies for producing on-the-spot wounds and injuries to be applied to stunt performers and extras. “We created a whole battery of generic appliances,” recalled Stoddard, “as well as some specific ones for burns and wounds. Will Huff oversaw the on-set application of prosthetics and makeups on performers, and he did a fabulous job. On a big day, he would have three makeup artists banging out fifteen to twenty burns or other injuries on set.”



Though many of the battle scenes were captured on Hawaiian locations, others required a degree of control that could only be afforded by filming in a tank. For shots of the doomed USS Tennessee, the production constructed full-size bow, gun turret and mast sections- with empty spaces between them- on the floor of the two-acre Fox Studios Baja tank in Mexico. When the oceanfront tank was flooded, the illusion of a complete, but swamped ship was created.

Some of the makeup effects helped to sell scenes of graphic violence– such as a shot of the West Virginia captain’s stomach blowing open in a blast, revealing his intestines. “At first,” stated Stoddard, “we were going to do an elaborate prosthetic appliance for that. But when we got to the set, Michael made it clear that he didn’t want it to be too graphic; so Will and I just sewed silicone intestines into the actor’s shirt, keeping much of it covered.”

“The filmmakers were trying to walk a fine line between be-ing respectful to veterans, keeping the ratings board happy, and yet showing audiences what these guys really went through,” Rosengrant commented. “The graphic realism shows you that the war wasn’t like an old movie from the forties. It was a scary, scary thing. In some little way, we tried to get that across on this film.”

Comprised of so many disparate elements– stunt and digital performers, computer generated water and live-action shot on the deck set in Baja– the Oklahoma sequence required a lot of tweaking in the compositing stage to create a seamless blend. Unstable live-action plates hampered the task. “On the original shoot,” stated Ben Snow, “there was an elaborate construction crane on the Baja tank, with the camera dangling from wires on a huge crane arm. So the camera was always moving a bit– it was not a locked-in motion control rig. Also, since there was an explosion on the main element of the ship rolling over, there couldn’t be people on the deck of the ship on those takes. In fact, it was too dangerous to have people anywhere near, even in the water. So they shot all that separately– an element of the ship exploding and rolling over, then separate passes of people running around on the deck of the ship.”

All of the separate passes and locations resulted in elements that simply did not match. “We started the shot by tracking the motion of the original hero background,” stated Marshall Krasser. “This data would then drive all of the other elements in the final scene. We tracked and stabilized all of the other non-CG elements, and applied the hero’s inverse data for the final lock-in. On that shot, we had four different passes we were trying to blend together– and that got a little tricky. Compositor Susan Weeks was able to use warping software to force the elements into alignment. We also had to augment the number of people in the water; and those elements were pulled from other shots and tracked, as well. Another problem was that we needed to add smoke elements that had been filmed in a number of different locations– Baja, San Rafael, Hawaii, Texas and Nevada– plus a couple of CG smoke plumes that Aron Bonar had



Practical smoke, fire and wreckage were added to the tank for live shots of the carnage.



For medium and close shots of the torpedo-struck USS Oklahoma listing in the water, John Frazier built a partial battleship set and mounted it to an underwater hydraulic gimbal that could rotate the construct 180 degrees. The 150-foot-long set could be overturned in a matter of seconds– with stuntmen and extras sliding on the deck– then set aright for the next take. Two sets of brakes enabled Frazier and his crew to maintain control of the 700,000-pound rig.

rendered. We had to make the smoke from all those different environments look the same.” Since a second, upturned Oklahoma hull set had been situated immediately adjacent to the gimbaled one, the compositors had to remove that from the plates. “Susan had to get rid of that overturned hull, as well as parts of Baja on the right side of the plate. That section was replaced with a matte painting, CG water and rendered boats.”

With the torpedo’s impact on the Oklahoma, all hell breaks loose. Low-flying fighter planes target the ground with gunfire, while higher-altitude bombers drop their payloads on the ships anchored below. Among John Frazier’s tasks at the Hawaii location was setting up an underwater air system to simulate gun-strafting in the harbor. Air—rather than more typical pyrotechnic charges—was employed as a safety measure since a number of extras would be in the water during the strafing shots. “We put in an electric air valve on PVC pipe every five feet for a 150-foot run,” Frazier explained. “We sank the pipe and valves six inches below the waterline—on floats anchored to the bottom of the harbor—and set it off with a nailboard-type thing. A big accumulator tank supplied air to it. It took a lot to set it all up; but once it was there, take two was a piece of cake. ‘You want to see that again? Okay. Poof! There it is.’ Nobody liked what it cost going in; but Michael and everybody else loved it once we had it, because we could keep doing these hit runs in the water as many times as we wanted. We didn’t have to do full runs all the time, either; we could set it up just to do random hits coming from the tailgunners. It was very effective.”

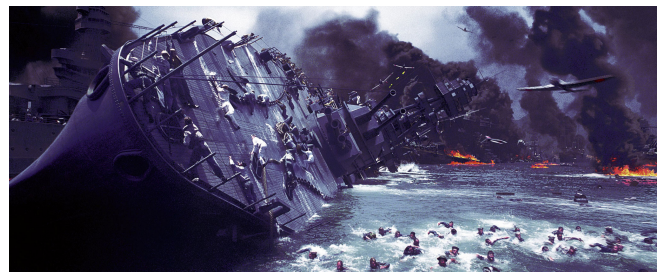
Frazier also created big plumes of water to simulate dropped bombs detonating in the harbor.

“We set off water explosions that rose seventy-five feet in the air using ‘kinepak,’ which is a type of dynamite,” Frazier said. “It’s really safe stuff, and it was set by special effects supervisor Archie Ahuna and his Hawaiian crew.” Local marine biologists patrolled the harbor prior to the detonating of the dynamite to ensure that no marine life would be harmed in the explosions. “It was their job to go into the water an hour before we set off any explosives, looking for turtles and sharks and other marine life. If they saw anything in the vicinity of the explosives, they’d chase it away.”

In post, ILM generated volumes of CG smoke, flame and gunfire elements to augment the practical pyrotechnics. “On Pearl Harbor, we did more CG smoke and fire than I think anyone



Dozens of stuntmen and extras—portraying sailors abandoning the critically stricken Oklahoma—swim clear of the warship in plate photography shot in Baja. Adjacent to the gimbaled bow was an upside-down hull set—also provided by Frazier—for a subsequent sequence in which rescuers attempt to save men trapped within the overturned Oklahoma. This second construct had to be digitally painted out of many of the earlier shots featuring the gimbaled set.



In final composites, ILM digitally extended the practical set—which represented only a fraction of the 600-foot-long battleship—and added digital stuntmen, CG planes and background ships, and both practical and digital smoke and fire elements. Digital water added turbulence to the placid tank water.

has ever done before,” Brevig stated. “In fact, we had to take a look at the process of rendering realistic smoke because there was going to be so much of it in this film. The volume of smoke you see in photographs of the actual Pearl Harbor event– you can’t make realistic smoke of that volume using normal particle simulations. And you can’t make it for real because it’s toxic. John Frazier did a lot of black smoke work in production, but it wasn’t nearly enough for the wider shots. We found that while those practical elements were good for dotting into the background, because of perspective change and the intimacy of the camera flying in and around the smoke, we had to simulate smoke on a huge scale.”

For visual reference, Michael Bay pointed toward an Imax film called *The Fires of Kuwait*. “It looked like a vision of hell,” Ben Snow recalled, “with huge expanses of black, billowing smoke– and Michael loved that. To get that sort of feeling, given that we had very elaborate camera moves to deal with, we realized we’d have to do some sort of big-style smoke development. So early on we got together with the R&D department, and asked, ‘Okay, how can we do this?’”

Since the roiling smoke would share some of the characteristics of water, the Pearl Harbor team conferred with John Anderson, Vishwa Ranjan and Ari Rapkin, who had been key to the development of dynamic simulations for the storms at sea in *The Perfect Storm*. “Our team,” said Snow, “which included Raul Essig and Carl Frederick, got together with the fluid dynamics team and did a lot of work on the simulator to make it work for us, adding some controls.” One control would enable the digital technicians to run a small-scale simulation– for the sake of speed and simplicity– that demonstrated, more or less, what the large-scale simulation would look like. “In the past, we’ve had to run the whole thing to see what it would look like– and that could take a week. We solved that problem to some extent with this show; but these simulations are still very elaborate, and they take a lot of computer and render time.” Another advance was a control that allowed the animators to save the simulation at a particular level. “There’s a lot of run-up time before the simulation begins to stabilize. It might take two days of processing just to get it up to the point where it even looks like a smoke event. With this function, we could get the simulation to a certain level, then save it and always be able to go back to that level, without having to create it all over again.”

CG fire was also developed for the show– though fewer R&D resources were invested in it, since it would be used primarily in conjunction with real fire elements. “We used a Maya simulation that sequence supervisor David Horsley worked out,” said Snow, “with a real element inside of that to give it some internal structure. The core section, which would lack structure in the digital element, was made up of this real fire element, with just the tendrils in CG.”

Tracer fire and bullet hits were yet another major R&D effort, overseen by Hayden Landis and Michael Ludlam, both of whom wrote a number of new tools and a user interface for animators that enabled them to add appropriate gunfire effects as needed. “It allowed the animators to animate a target– where the guns were firing– as well as the rate at which they fired, how many tracers would be fired, et cetera,” stated Landis. “It created the muzzle flash, as well as the little smoke trails left by the tracers. It was somewhat automatic in that, just by hitting a button, we could get about seventy percent of the way there. Then the animators would tweak it, depending on the shot. If something came really close to camera, they might have to adjust the shaders; but, basically, this tool gave us the appropriate particles. Those particles were then

taken into our rendering packages and rendered as smoke or as a tracer.” The second part of the gunfire tool dealt with hit points. “That was for a tracer or bullet that is not visible itself, but creates a hit, impacting the environment in some way. It was a tool that said, ‘If this type of gun hits this type of object, trigger this event.’ So if you were firing a .50 caliber bullet at water, for example, it would trigger a splash. If it hit a boat, it would trigger a spark or a piece of debris to fly off. If it hit pavement, it would spew up some pavement. This tool managed all of that.”

Another prominent shot in the Pearl Harbor attack sequence- and a highlight of the film’s trailer- has the camera following a bomb all the way as it drops down from a bomber plane to the deck of the USS Arizona. The bomb drop shot was nearly one-hundred-percent digital. “Production had filmed an aerial plate dropping down,” explained Alex Jaeger, “but the camera move wasn’t fast enough. So we had to tile together stills from the background and make a whole environment that we could drop our virtual camera through. Everything in that shot- the ships, the planes, the people, the water, the bomb, the smoke, the fire, the sky- was computer generated by a team headed by technical director John Helms.”

“That was a very difficult shot,” Ed Hirsh asserted, “because the design of it was so stylized, so unrealistic. It was something you could never do in real life- shoot that bomb coming out of the plane and then follow it all the way down- so that meant we had to work that much harder to make it look real. It took a lot of finessing to get it just right. We worked on it a long time to make it look as if a camera operator was really shooting this - getting it not too perfect, with just the right kind of camera wobble. We experimented with how close we could get and how much camera move to put on it- anything to take the curse off this digital shot.”

In the film, as in reality, the bomb’s destructive power is magnified significantly due to the fact that thousands of pounds of munitions were being stored on the Arizona. Upon the bomb’s impact, the ship bucks like an angry horse, then disintegrates in a massive blast. The design of the shot evolved from actual newsreel footage of the vessel’s demise. “In the real footage of the Arizona blowing up,” commented Jaeger, “the ship doesn’t lurch out as much as it does in this shot. But Michael wanted to see something really dramatic and different- something you’d never seen before. So we based it more on verbal descriptions of the explosion than on the



The film intercuts between the attack on battleship row and the bombing of several nearby air installations. Pilots and ground crews run for their planes as Japanese Zeroes target a squadron of P-40s parked on the tarmac. The live-action plate was augmented with CG tracer fire and CG planes- both in the air and on the ground. Bags of fuller’s earth rigged with charges produced safe but effective pyrotechnics as the actors ran through the combat zone.



Several pilots make it to their planes to engage the Japanese in air-to-air combat. An aerial view of a Zero chasing a P-40 over the battle-damaged airfield. The foreground Zero was synthetic, while the P-40 was a real plane captured in the original plate.

actual footage. We wanted to convey that sense of the inside of the ship exploding first, then ripping the hull open- which is what actually happened.”

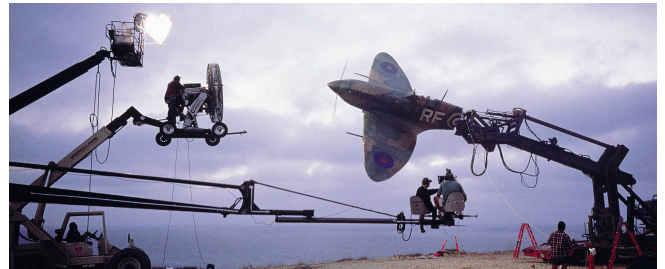
To animate the buckling ship, animators started by putting the CG model through a rigid-body simulation tool devised by Jim Hourihan and Jeff Yost- the same tool that would be used for shots of exploding airplanes. “The whole ship was set up in sections, lengthwise down the hull,” stated Scott Benza. “Then a blast-force was placed underneath these sections, where the actual explosion took place. When it was run through the simulation, the sections would blow apart. In addition to that software, we had a custom water-field written just for that shot, which allowed us to ‘float the boat’ using simulation code. So once the ship came up in the water, it would come back down and float naturally- all within a single simulation.” The model itself was a special ‘breakaway’ version, rigged so that certain areas would come apart more easily and violently than others. Technical director Hilmar Koch enhanced the shot, adding procedural debris and explosion elements.

While shooting live elements of the Arizona destruction on board the Texas, Michael Bay had a last-minute inspiration- a shot looking up from the deck of an adjacent ship as that ship’s tower falls into frame and impacts the Arizona’s tower. Brevig filmed the plate- minus The Two Towers- and back at ILM, Alex Jaeger used it as the basis for an animatic. “They just gave me the plate,” remarked Jaeger, “and said, ‘Make something that looks cool.’ So I did this animatic; and later they used that to shoot miniature towers crashing into each other.”

The model shop crew- under the direction of Bryan Dewe- fashioned two miniature towers for falling, and one tower that would be impacted in the shot. All of the towers were 1/6-scale and were made primarily of steel, with collapsible areas consisting of soft lead. The tower models were filmed outdoors in the Nevada desert toward the end of postproduction. “The tower collapse was rigged like a big mousetrap,” stated Geoff Heron. “Everything went once we triggered it, with all of these mechanisms firing in sequence. One tower didn’t have to move at all- it just was there to get hit. The other tower would fall forward, landing about a foot from the camera- so we had to have a lot of control over that one. That second tower had a gimbal on a turntable attached to the mast with two stays. One of the stays guided the roll of the tower; the second stay we tethered and then cut loose at a certain point. The whole gag was triggered with a pneumatic cylinder.”

Though an explosion element would be composited into the background of the shot- as the motivating factor for the collapse of the tower- the foreground of the miniature setup was kept free of fire and smoke to avoid complications when compositing in people from the live-action plate. “We had to build the upper decks of the Texas, as well, so we could save all the live-action people they’d shot on that ship in the plate photography,” related Michael Lynch. “Essentially, the Texas acted as a stand-in set- just something that allowed production to get the action of actors running around on the decks and jumping off. Then we replaced the whole plate photography with our miniature, lining it up so that when the people ran down stairs, for example, their feet would land perfectly on the miniature stairs. Everything in the plate was replaced except for the people running around and a foreground gun operator.”

The film cuts back and forth from battleship row to airfields nearby, where both grounded and airborne American pilots engage in combat with the Japanese planes. In an early airfield shot, a pilot attempts to lift off in his P-40, but disintegrates in midair when his plane is shot down by attacking Zeroes. John Frazier's team launched and blew up a number of mocked-up fiberglass P-40s for this and other such shots. "We made what we called a plane launcher," Frazier said. "It was a big tube with an accumulator tank on the back. We pumped it up to about 1400 pounds of pressure, and used it to launch full-size, lightweight airplanes about 300 feet. We used it for planes taking off and not making it, or planes that just plow into towers and buildings. We'd put charges in the plane, then point it at something and launch it- and it would blow up on impact."



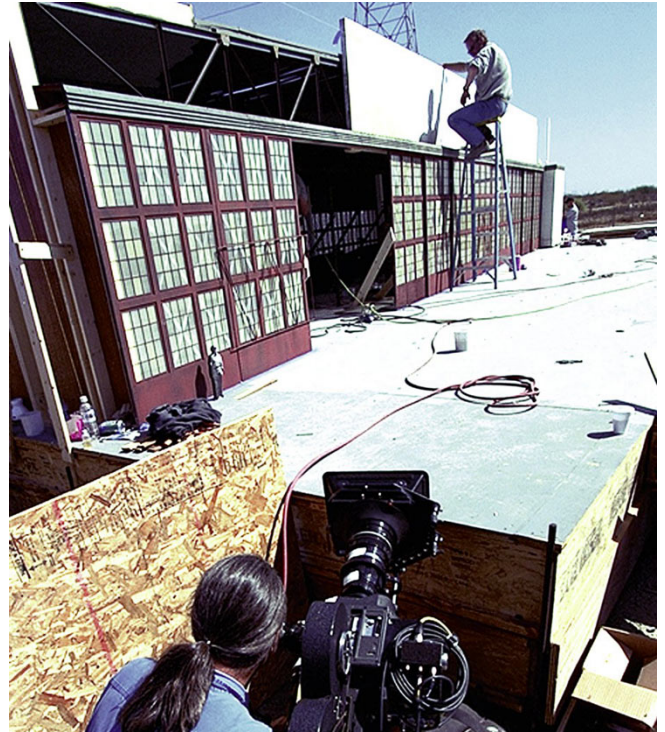
Cockpit closeups of actors were shot on a partial plane mockup mounted to a gimbal to effect banking and rolling maneuvers.



A P-40 is shot down as it attempts to take off from mechanics row. The shot was accomplished by launching a lightweight mockup plane- filled with pyrotechnics that could be detonated remotely- from a John Frazier catapult rig. The catapult could launch the mockups up to 300 feet in the air. Digital artists at ILM painted out the rig and added CG smoke and debris.

Although the practical launch rig proved useful for some of the crashes and aerial explosions, more often such events were achieved with a computer simulation. “We used the rigid-body simulator that we’d tweaked over the years,” stated Ben Snow. “We decided we really needed to rework it drastically for this show so we could get more highly detailed, break-apart effects for planes blowing up. The airplane models had three hundred to a thousand little bits that shot off as a primary break-apart effect, and then a lot of secondary animation that we added.” The rigid-body simulator, written by Jim Hourihan, worked in conjunction with breakaway plane models fashioned by Bruce Holcomb in Alias Studio. “We could assign properties to each of those breakaway pieces, and then join them together with little springs and connectors. Once we had done that, we could just pass that plane through the simulation to make it explode. Even though it has been a complex thing to do in the past, this had enough controls and enough usability that we could have the animators run the simulations, rather than the TDs. That way, if there was still some hand animation that had to be done after running something through the simulation, the animator could just do it.” The shot of the P-40 exploding as it attempts liftoff featured the detonated practical plane, replaced in mid-shot by the CG plane simulation, fire elements shot on the ILM backlot, CG smoke, tracer fire and muzzle flashes. Ron Woodall painted bullet holes on the wings of the model, revealed one by one as the plane is hit by gunfire.

In the course of the airfield attack, a hangar explodes—another combination of Frazier’s full-scale pyro and visual effects. Since extras were running near the structure during live-action shooting, Frazier’s pyro work was relatively low-key, intended primarily to throw interactive light on the performers. The real explosion was executed months later by ILM’s miniatures crew,



The model shop fashioned a sixth-scale miniature for a scene in which a targeted airfield hangar explodes. Modelshop supervisor Michael Lynch dresses the hangar model as director of miniature photography Kim Marks lines up the shot.



Pyrotechnician Geoff Heron triggered a closely-timed sequence of explosions to create the appearance of one massive blast.

which built a 1/6-scale, forty-foot-long replica of the building. Geoff Heron blew up the model on the ILM backlot. Its composition of pyrocel and 1/32-inch sheets of glass created a spectacular disintegration effect, captured in-camera by director of miniature photography Kim Marks. "Blowing that miniature up was a big deal," noted Heron. "We mounted a bunch of mortars inside the structure- even though, historically, only one bomb went in. If we had made a single bomb and set it off in the middle of the miniature, it wouldn't have looked very dramatic- it would've happened too fast, and we wouldn't have been able to capture it in a dramatic way. Instead, we used softer charges, set to go off sequentially. It still looked like one big explosion, but it was actually several staggered ones."

The aftermath of the Pearl Harbor attack features a wide view of the devastation- a somewhat after-the-fact addition to the shot load that required the CG battleship model to be modified with scorch marks, holes and other indications of severe damage. "Initially," recalled Brevig, "we didn't know we were doing any CG ships in the aftermath sequence. It had been filmed in Baja on a number of different set pieces- and we had thought it was a done deal. But as the sequence was being assembled, I said to Michael Bay: 'We don't have any wide views of the aftermath, and the audience is going to feel cheated if they don't get to see it.' So we had to show these ships, after the attack, which are much more damaged than the earlier versions we'd built in CG. One of them is upside-down, one is sunk, and they all have fires on them. That required us to make distressed versions of the models. We basically just kept smashing them and changing things and repainting scorch maps and so forth. We also fine-tuned all the individual model pieces that were on the decks- for example, lifeboats or airplanes that were on these ships had to be broken off and tipped over."

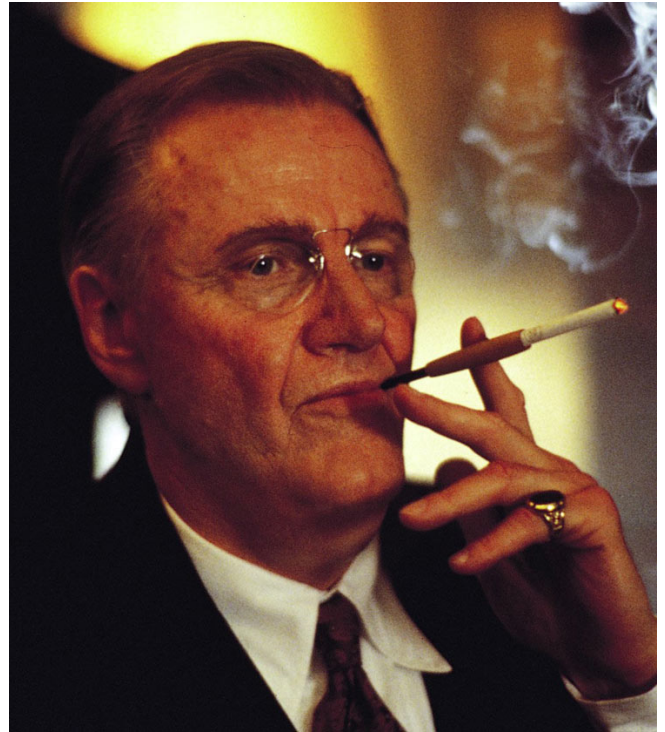


A wide crane shot reveals the devastating aftermath of the attack on Pearl Harbor. The only practical elements in the haunting shot were the overturned Oklahoma set photographed in the Baja tank, and the boat carrying Pacific Fleet commander in chief Admiral Husband E. Kimmel and his staff as they survey the damage. Burning battleships, billowing black smoke, sailors in the water and various rescue craft were all computer generated, with a matte painting providing the view at the horizon.

In adding destruction effects to the CG models, ILM artisans adhered to the historical record. "The West Virginia, for example, took five torpedo hits along the side of it," remarked Ron Woodall, "so we modeled in five gaping holes. On the Arizona, an entire tower had leaned forward, almost collapsing into the water; and we modeled that in, as well. The general public probably wouldn't know the difference, but everybody wanted to be as accurate as possible."

In the story, as in real life, the U.S. Navy and the U.S. Army Air Corps plan a counterattack on Tokyo, at the urging of President Roosevelt. Besides providing injured sailors and civilians, the Stan Winston crew created an FDR makeup for Jon Voight. Production had originally envisioned casting an actor who more closely resembled Roosevelt, making a major makeup job unnecessary. But that approach changed when Voight was cast in the role- especially since the actor himself was eager to wear the appliances. Prior to a meeting with Voight, Bay and Bruckheimer to discuss the possibility, John Rosengrant and fellow Winston supervisor Shane Mahan sketched an FDR likeness on top of photographs of the actor, just to assure themselves that such a makeup was doable. "It's very difficult to make somebody look like someone else," stated Rosengrant, "particularly when that someone else is a famous person. But by the time I went to the meeting, I was convinced I could do this makeup."

Rather than design a makeup that would totally reconfigure Voight's features into those of FDR, Rosengrant concentrated on a few distinctive characteristics. "Roosevelt's nose, chin and neck were the defining things," commented Rosengrant. "The neck- especially the 'wattle' in his neck- was particularly important. That was one of FDR's most noticeable features, at least at the time of Pearl Harbor- he was famous for that line from his chin to his neck. We also changed the ear tips, because FDR's ears were very different from Jon Voight's. We went in with the idea that these few appliances would create the essence of FDR, still allowing Jon Voight to come through."



In response to the sneak attack, President Franklin Delano Roosevelt petitions Congress to authorize the United States' entry into World War II. John Rosengrant of Stan Winston Studio supervised the design and creation of a prosthetic makeup to transform actor Jon Voight into the former president.



With a focus on particularly distinctive facial features, artist Greg Figiel sculpts the FDR likeness on a lifecast of Voight.

The FDR-like features were sculpted onto a lifecast of Voight; and from there, foam rubber appliances were produced for the nose, chin, earlobes and neck. The foam neck piece was filled with water to give it weight and make it hang realistically. Once on set, Will Huff applied the makeup, painting the foam pieces in such a way as to take the curse off the rubbery texture. "The way Will painted it, you couldn't tell it was foam rubber," noted Rosengrant. "It looked dynamite. We did gelatin pieces, as well, on the nose and the ears, to take advantage of the translucency; but we also had an all-foam set. In all, we ended up building six or seven sets of makeup." The transformation was completed by cutting and thinning Voight's hair.

As always, the ultimate success of the makeup depended on the actor's ability to breathe life into the character. "All of the work that we put in would have been for naught had it not been for Jon's performance," Rosengrant said. "He was a joy to work with through the whole process because he was so receptive to the idea to begin with- and some actors are not. But a makeup really can enhance a performance. Jon did an enormous amount of research on FDR, and even had the right kind of leg braces built. When he did a test here for the first time, and we saw him in makeup and with the braces on, people were rushing over to help him up. It was pretty amazing. We looked at him and really got the feeling that FDR was there."

Roosevelt orders a retaliatory bombing raid on Tokyo, led by Lieutenant Colonel James H. Doolittle (Alec Baldwin). The high-risk mission, carried out a little more than four months after the Pearl Harbor attack, called for sixteen B-25 bombers to take off from the flight deck of an aircraft carrier- the first time such a feat had been attempted- drop their bombs over an industrial district of Tokyo, then land in mainland China, where the pilots would rely on the aid of peasant soldiers to hide them and get them back home. Architects of the plan knew full well that the raid would inflict little real damage on Tokyo, but would, nonetheless, deliver a powerful psychological blow to Japan. The success of the top-secret mission, and the sheer audacity of it, sent America's morale soaring, making the Doolittle raid America's first real victory of the war.

The sequence was comprised of bits and pieces shot all over the world. The aircraft carrier transporting the B-25s was portrayed by the USS Lexington, the period carrier docked in Corpus Christi. "It had all of Corpus Christi next to it and behind it," said Brevig, "so we had to remove the town digitally and surround the ship with water and the complement of ships that accompanied it as it headed toward Japan. We also populated the deck with B-25s. There were only five or six real ones there, and we lit and matched our CG planes to those to create the entire fleet of sixteen. When the planes take off, some are real B-25s taking off from the Lexington; others are synthetic."

A subsequent shot shows the entire fleet of B-25s airborne. "You see them flying over the ocean," stated Ed Hirsh. "In that shot, the first three airplanes were real, but all of the rest were synthetic. That was a good example of a shot where we had to have all the subtleties of flight in the animation, since the real and CG planes were together in the same frame. They had to have the right weight, the right movement- and also the right lighting, with all the little glints you'd see. Michael Bay likes very snappy lighting. He liked things to be nice and contrasty in the live-action, so we had to match that in our elements."

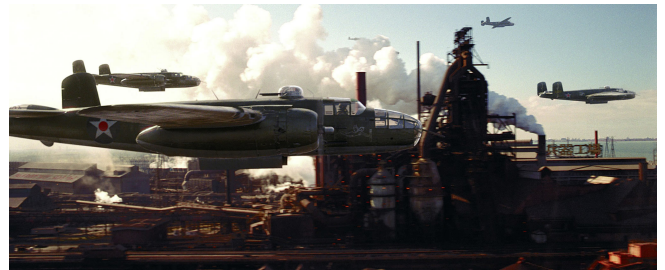
Aerial live-action plates representing Tokyo's industrial area were shot over Gary, Indiana. "They needed a large factory, and wanted something that was fairly close," noted Brevig, "so Gary seemed to be the place. Ed Hirsh shot aerial plates of the U.S. Steel factory, from a helicopter, and then we composited in CG B-25s." Shots of the bombing of the Tokyo district were accomplished with a seven-thousand-square-foot, 1/8-scale model- built under the lead of Robby Edwards and filmed in the Nevada desert. "This model was supposed to represent about twenty-two city blocks of an industrial area of Tokyo," Michael Lynch remarked. "But it wasn't really based on the real area in Tokyo that they bombed during the Doolittle raid because we had to make sure it matched the plate photography filmed over Gary. Fortunately, warehouse and industrial areas around the world don't have many dissimilarities. We hoped that signage and a few flags would help sell the fact that it's Tokyo. We had all the appropriate Japanese characters on the signs and on the buildings, and we tried to make sure we didn't misspell anything or offend anybody. A colleague in Japan provided us with some of the characters; and there was someone in the art department who spoke Japanese who also helped out."

The final model included twenty-five buildings, six of which were done as breakaway pyro structures. "We didn't use pyrocel for these pyro buildings," said Lynch, "because it doesn't travel well. I couldn't risk having the models reduced to powder by the time they made the trip down to Nevada. So we built the pyro buildings out of wood or brick, with a lot of corrugated aluminum roofing on them." The model was shipped to Jean, Nevada- a remote area situated between Las Vegas and the California state line- accompanied by a small model photography crew, led by Kim Marks. "We had 150 linear feet of semi-trucks full of models that went down there. Everything had to be built at ILM, then crated, loaded up and trucked to Nevada, then uncrated and reassembled when we got there. The largest building was twenty-six feet long, fourteen feet tall; and there were several other big buildings that had to be completely broken down and reassembled there. A few of the buildings were small enough to travel in one piece."

The film crew was hampered by stormy weather conditions. Sixty-mile-per-hour winds blew away four unattached building roofs- one of which landed a full mile from the shooting site, where it was later found leaning against the fence of a women's prison. "The wind blew a crate



In the film, as in history, America responds to the Pearl Harbor attack with the Doolittle raid- an audacious and high-risk aerial assault on Tokyo that required large B-25 bombers to take off from the USS Hornet in the waters near Japan. Synthetic planes were composited into shots of real B-25s taking off from the deck of the USS Lexington. Anachronistic objects on the ship's tower were painted out and replaced with ocean elements.



For views of the Tokyo industrial area targeted by the Doolittle raiders, Ed Hirsh supervised the filming of aerial plates over a steel plant in Gary, Indiana. CG B-25s were composited into the plate photography.

over and sent all the roofs inside of it tumbling away,” Lynch recollected. “I had to send people out on bicycles to find the pieces. The next day, we had an inch and a half of snow on our set. It looked great, actually– but it didn’t quite fit with history. In the few days we were there, we had wind, rain, snow, frozen ground; and then other days, we’d have 80-degree weather.”

To simulate an aerial view of the bombing, the camera was mounted to a cable suspended between two cranes set 350 feet apart and at a height of 35 feet. An endless drive setup that was attached and powered by a truck below allowed the camera to traverse the length of the cable. Remote switches operated both the camera and the pyrotechnics on the miniature, which were timed so that specific events would be captured by the camera at specific points in its flight from one crane to the other.

The setup had been designed for two takes; but Michael Bay bought off on the first one– with the provision that the second be used to shoot additional action from ground level. “We had to scramble to turn what was always intended to be an aerial shot, with our roofs the hero parts of the model, into a ground-level view,” remarked Lynch. “In two days we had to make more signage for the buildings and reconfigure our model to make it look hero enough from that angle. Fortunately, we took a lot of raw materials down with us– enough hardware and materials to make the buildings look decent from the ground. That whole sequence now consists of the cable-rig shot, the ground shot, and the plate photography captured in Gary. We also filmed six exploding miniature buildings separately against bluescreen, and those elements went into the Gary plates, as well.” Bluescreen people in the foreground and background digital characters running away from the assault were also composited into the model and plate photography.

In the movie, Danny’s B-25 crashes on mainland China. The lead-in to the crash was done as a rear-process shot, on stage in Los Angeles. “We made a kind of car-flipper rig,” recalled John Frazier, “except that it was covered with a patch of grass. As soon as Michael Bay gave the cue, we would launch that thing and it would flip up just like a mousetrap and strike the front of the airplane. It created the illusion that the plane just nosed right into the grass field.” Another live-action element– which picks up just after the plane has nosed into the ground– was shot at the Disney Ranch outside Los Angeles, with a post-crash B-25 set piece.

Rafe’s plane, too, crashes on the mainland, executing a hard belly-landing in a rice paddy. The scene cuts from a live-action composite shot of the plane coming in over treetops to a miniature shot that used a 1/6-scale B-25. “It was a fiberglass shell of the whole plane, covered in metal foil so it would crumple,” said Lynch. “We made it so the port-side wing ripped off, part of the cowling broke, and the propellers twisted when it hit the ground. The front glass windshield also shattered. It was shot on our stage using a hydraulic rig built by Geoff Heron.” The miniature plane was mounted to the rig and shot high-speed as it made contact with a rice paddy miniature.

Aerial skirmishes over England– featured earlier in the film and culminating with Rafe’s Spitfire being shot down over the English Channel– required their own slate of effects work. Live-action for the scenes was shot during the last week of filming, when the production took a very small unit to England to shoot actors climbing into and out of full-size Spitfires. David Nowell was

there, as well, filming aerial photography over the English landscape. Closeups of the actors in the airplane cockpits were shot on stage, on a mockup cockpit attached to a Frazier gimbal that provided bank and roll movements. “They had a great mockup Spitfire on a rig,” stated Ed Hirsh. “Ben Affleck could climb into this thing, and the rig would move it around. At one point, they took it out to a spot in L.A. overlooking the ocean and shot it against the sky and water, which looked great.”

Prior to postproduction, the entire air battle sequence consisted of nothing more than the live-action and aerial plates captured in England and these cockpit closeups. “Production didn’t have any of the German airplanes– the Messerschmitts, which are the fighters, or the Heinkels, which are the bombers– so they didn’t have a sequence cut together,” related Brevig. “So we made animatics for the entire sequence and designed and completed our shots based on those.” Ninety percent of the dogfight sequence was created synthetically, with CG Heinkels, Messerschmitts and Spitfires intercut with replica planes from the era. Midair explosions utilized the revised rigid body simulation employed for other dogfight sequences.

To augment the aerial photography, the CG team took photographic stills of the English landscape– shot from a helicopter over the cliffs of Dover– and stitched them together to create a 3D cyclorama. “We also took all the ocean technology we had developed for *The Perfect Storm* and made a CG English Channel,” remarked Joel Aron, sequence supervisor for the British battle sequence. “So at that point we had a huge English Channel and a huge sky that we could do anything in.”

One of the shots in the sequence features Rafe in a Spitfire, tailing and firing upon a CG Messerschmitt, modeled by Shadi Almassizadeh. “Ben Affleck’s Spitfire is right behind the Messerschmitt,” recalled Aron, “and the camera is in front of it. So we see Rafe’s plane come down and shoot the Messerschmitt, which then spins over and impacts with the water as the Spitfire flies overhead. Michael Bay was concerned that the shot look as real as possible; so Ed Hirsh and



Shots of the Tokyo bombing called for the building of an eighth-scale miniature. Eric Brevig, Ed Hirsh and visual effects producer Janet Lewin map out the bomb run on a rough cardboard mockup of the industrial complex.



Visual effects art director Alex Jaeger tends to final details on the pyro-rigged miniature, which was assembled in the desert outside Las Vegas and filmed by a camera that traversed a cable between two cranes. The model team had to quickly redress the miniature– built only for the

the miniature effects crew welded up the sides of a dumpster and filled it with water to create practical splashes to enhance the shot.” In the final shot, the German aircraft is hit, then explodes and nose-dives upside-down into the water as the camera leaves it behind. “For inspiration, I referred a lot to the car chase in Bullitt where the Charger flips over at the end and the camera continues to pull away from it as you watch this explosion in the background. That was the look I wanted.”

aerial view, when Michael Bay requested additional ground-level shots. Signage and other details were fashioned on the fly, then applied to the model. After dropping their bombs on Tokyo, the B-25s—some real, some synthetic—evade flak from Japanese anti-aircraft guns. The flak was computer-generated. To ensure a dead-on match between real and synthetic aircraft, the real planes were hoisted on a rig and photographed from every angle. Those photographs were then digitized and used to create texture maps for the CG aircraft.

Another shot of a German bomber exploding would become the source of a kind of cosmic payback for at least one member of the effects team. “The Heinkels were known as the planes that did most of the damage to London during the aerial assaults,” commented Aron. “One of our animators on the sequence was Paul Kavanagh, who is not only British, he is extremely British. So he loved working on this bomber shot— a closeup, three-quarter view of a synthetic bomber against the sky, blowing up spectacularly. Paul was always saying, ‘These blokes bombed my granny,’ so the shot had some special meaning for him. In fact, one of the bombs has written on it, ‘For Paul’s Granny’ in German. The gunner who is in the bomber was painted by Ron Woodall to look like me, while the pilot looks like Ron. Ron and I would come in on the weekends to detail these shots as much as possible— down to greasy fingerprints on the bomb.” Though that shot, too, was primarily synthetic, a quick close-up was augmented with a Heinkel nose-section model, built in 1/3-scale. “The CG Heinkel looked great,” noted Michael Lynch, “but the thinking was that it would be easier to get a big explosion with a model than with the digital version. Our hero comes in from behind and shoots the nose of the bomber, which is all glass, and it explodes. So we constructed the nose-cone, which was about twenty-eight inches in diameter, and Geoff Heron blew it up.”

Near the end of the dogfight sequence, Rafe’s Spitfire is hit and begins spiraling downward toward camera, which follows the doomed plane all the way to its impact with the computer-generated English Channel. “The shot is seamless,” remarked Aron. “By having the 3D cyc, we could create this kind of camera move on the plane, and also add smoke and contrails and ‘more war’ to the background— which was always Michael Bay’s number one request.” Live-action elements of the downed Spitfire in the English Channel were captured using a practical rig in the tank in Baja.

Considering the epic scale and action orientation of Pearl Harbor— not to mention Michael Bay’s signature quick-cut style— 211 shots seems a modest effects slate, especially in this era of 500-plus-shot effects films. But the shot count is grossly misleading. “The achievement in this film,” concluded Eric Brevig, “was creating the incredible density of events in each shot, not the number of individual shots themselves. The complexity of any one shot was such that might normally go into ten isolated event shots. The number of elements was probably equal to a 500-shot show; it’s just that we put them into these hero, spectacle moments. What Michael wanted, and what we rose to the challenge of creating, were shots where the camera flies down past twelve burning battleships, or pushes right next to a ship that is literally turning over; and

while that is happening, the tower of the ship breaks off and falls into the water, the sixteen-inch gun explodes, and people fall to their deaths- all captured in one long event. The subject matter lent itself to these kinds of sustained moments. It's so awesome and horrifying, you just can't look away."

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ACCELERATED EVOLUTION

image

ARTICLE BY BRAD MUNSON

The mysterious object hurtling towards earth in the opening scenes of *Evolution* is not a spaceship. It does not have a pilot or a crew, and it carries no intelligent life- at least, none that we can see. But this seemingly innocent chunk of space debris is, in fact, the spearhead of an invading force. From the instant the meteor crashes in the Arizona desert, it begins to establish an alien environment that is fundamentally hostile to humans. Springing from a single microscopic bacterium, whole new species evolve and spread through a network of underground tunnels to threaten nearby natives. Left unchecked, the adapting ecology will produce lifeforms that can live independently on earth...and from that moment on, humankind will be doomed. Learning of the imminent invasion, a small group of renegade scientists and citizens band together- hampered by a hostile military- to stop the advancing alien ecology before it destroys the entire planet.

Although the premise of *Evolution*- director Ivan Reitman's latest movie from DreamWorks- is reminiscent of past horrific alien-invasion pictures, this one is played primarily for laughs. At Reitman's urging, screenwriters David Diamond and David Weissman transformed Don Jakoby's serious screenplay into a comedy adventure that was both scary and funny. As with Reitman's earlier *Ghostbusters* films, visual effects for the project would be extensive. Rather than a single 'monster' or alien, *Evolution* would require the creation of an entire ecology. What's more, DreamWorks wanted a fast turnaround, with only a year between Reitman's first involvement in early summer 2000 and the film's initially scheduled midsummer 2001 release.



In the hands of director Ivan Reitman, *Evolution*- originally penned as a legitimately scary science fiction thriller - evolved into a high-concept comedy about sinister extraterrestrial lifeforms unleashed when a meteor crashes in the Arizona desert. Alien microorganisms discovered by community college professors Ira Kane (David Duchovny) and Harry Block (Orlando Jones) quickly evolve into increasingly more sophisticated- and more lethal- lifeforms. Dismissed by government agencies investigating the sightings, Ira and Harry search out and ultimately dispatch the alien invaders with the help of wannabe firefighter Wayne Gray (Seann William Scott).



Artists at Tippet Studio, the primary effects house on the production, designed and created eighteen alien creatures representing an entire Evolutionary arc- from flatworms to amphibians to mammals. Effects art director Peter Konig and

visual effects supervisor Phil Tippett pose with creature maquettes produced by the studio.

With so little time and so many effects-oriented elements to design and produce, it was clear from the outset that Reitman would have to begin working with his effects talent early. "This wasn't about one dinosaur," Reitman related, "or even a bunch of dinosaurs. It was about creating a whole new world." Production designer J. Michael Riva joined the project almost immediately, as did visual effects producer Nancy St. John. Concept artist Yuri Bartoli, on loan from DreamWorks subsidiary Pacific Data Images, was brought in to work on preliminary drawings with Reitman, and would find himself involved in *Evolution* for most of its one-year production cycle. "Working with Ivan was a lot of fun," Bartoli stated. "He was open to new ideas, so you could bring anything to the table. But he knew exactly what he liked and what he didn't like. That helped me, because I could channel my efforts in a direction that was in sync with what he was looking for."

Meanwhile, Nancy St. John was charged with building a budget and putting together a visual effects team that would bring *Evolution* to life. One of her earliest recruits was special effects supervisor Burt Dalton. "I had to do a visual effects budget long before anyone else was involved," said St. John, "so Burt and I spent a considerable amount of time going through the script together, figuring it out. I would say: 'Now, Burt, what can you do to make this easier for me? What could we do that would give us most of what we need in the plate, so that we would just have to enhance it with digital effects?' Burt came up with a lot of great ideas about how to help us pull off an effect, one way or another."

From the outset, St. John knew which visual effects company she wanted to rely on to bring in the film's many character animation shots. Though she had worked with Reitman only once before, briefly, and she had never worked directly with Phil Tippett, she had a hunch the two of them would make excellent creative partners. "When I read the script and saw the kind of effects that were in this movie," St. John recalled, "I told Ivan: 'We can bid it out to the world, if you'd like; but my recommendation, given the shortage of time, is to find a creative partner that you like, and then work with him from day one to get this movie made. And this is a Phil Tippett show.' Ivan said, 'Who's Phil Tippett?' And I said, 'Believe me, he's your guy.'" St. John's hunch proved right from the very first meeting between director and visual effects veteran. "They got on really well. It was kind of an immediate feeling of: 'Okay, I trust you, I like you, I think you're good creatively. Let's just go for it.'"

Tippett experienced the same immediate, positive connection. "I have a real strong way of saying, 'I think this is the way this stuff ought to be done, and if you don't want to do it that way, fine, but then I don't want to do it,'" Tippett acknowledged. "But I was very comfortable with Ivan from the start, and I think he was with me."

In June 2000, Reitman and producer Dan Goldberg sat down with key production and effects players to plan the show and begin conceptualizing the alien components. Tippett Studio art director Peter König focused on designs for the alien creatures, from microscopic to massive. "We had a couple of production meetings with biologist Dr. Mark Shelley, laying down ground rules for the whole thing," Tippett noted. "The aliens that come to earth on a piggyback ride on this meteor could have been really weird and wacky; but gradually, we narrowed our ideas

down to those based on the notions of ecologist/philosopher Phillip Gould- the idea that life itself is a dangerous thing." Gould postulated that Evolution on earth would never take precisely the same path twice. If you were to 'rewind the tape' of terrestrial Evolution in an attempt to duplicate the results, different forces and processes would cause an entirely different outcome. "That was basically our premise. The alien crashes; and whatever it is, it's life. It takes earth's DNA, crunches it up, and starts up a parallel track, an accelerated path that moves through our terrestrial Evolutionary development: single cells to multi-cells to flatworms to crustaceans, insects, amphibians, reptiles, and on and on. The premise necessitated that we create that entire Evolutionary arc."

Reitman had strong ideas about the look of the creatures, believing from the outset that they should have some connection to the look and feel of earth creatures. "They were aliens," said Reitman, "but there had to be some sense of reality about them- exaggerated forms, perhaps, but something with which we could still identify." To ensure that his vision of the aliens was realized, Reitman remained in close touch with Tippet and his team of designers, who, each week, would deliver stacks of concept drawings and sculptures to the filmmaker's office for comments and suggestions.

By July 2000, the script had been broken down into a slate of visual effects shots, beginning with the meteor in space tumbling towards earth and crashing into the Arizona desert, where it punches straight into the ground and forms a giant cavern. From that seminal event, a variety of creatures evolves hour by hour: first single-celled alien organisms, then multi-celled versions of same, then 'flatworms' that grow in size from as small as a fingernail to as large as a human hand. Alien insects and small predators next appear. A leech-like creature escapes into a nearby golf course's filtration system, and, later, an alien amphibian with a predatory feline/alligator look takes up residence in the course's lake. Next, the aliens evolve into land-dwellers. A dog-like animal, as much slug as mammal, makes its way to the suburbs. A whole collection of winged aliens, looking a bit like dragons or pterodactyls, escape the cave and die in earth's toxic atmosphere- until one evolves into an oxygen-breather. Finally, the Evolutionary arc reaches its penultimate stage with vicious alien primates. Before the next stage of Evolution can be reached, an ill-considered attack by the U.S. Army causes the entire alien ecology to fuse together, forming one massive meta-organism that breaks free of the cavern and threatens the entire planet.

Though there was no limit to the number and fantastic nature of the creatures conceived in the design phase, the logistics of actually producing them- through whatever means- had to be rooted in fiscal reality. "It is always a numbers thing," Tippet allowed. "We know we can do this many of this kind of shot for this many dollars in this amount of time. And the studio says, 'I don't want to pay that,' and the director says, 'I want more shots.'" The tug of war between creative decisions and those based on budget was eased somewhat by the fact that Reitman served as both director and producer on the show. "Ivan had to wear two hats, and you could actually see him switching. As the director, he'd say, 'I want all this stuff'- and our eyes would roll back in our heads, and we'd say, 'Oh, man, you're never going to be able to do all that.' Then he'd say, as producer, 'Okay, what can I do?' And then we could start talking reality. There was a lot of negotiation; but it wasn't contentious, and it worked."

Those negotiations resulted in a roster of eighteen different creatures- some of them alternate versions of the same creature- which translated to approximately 200 character animation shots. The number rivaled the Tippett Studio shot count for *Starship Troopers*; but whereas that film had enjoyed a full year of preproduction and yet another year of production, *Evolution* would be produced in about fourteen months- or so the filmmakers thought.

Just as work was beginning, DreamWorks informed Reitman that the movie's release date had been moved up six weeks, to June 6, 2001. Faced with the truncated schedule, Reitman and his producers agreed that no one facility would be able to produce all of the visual and physical effects. Working with Tippett, Nancy St. John assembled a team of vendors. While Tippett Studio would retain the majority of the character animation work, Pacific Data Images would take on thirty shots, including the opening meteor in space, its explosive crash-landing in the Arizona desert, and some of the earliest alien lifeforms. Alec Gillis and Tom Woodruff, Jr., were tasked with providing the alien primate suits through their Amalgamated Dynamics Incorporated, while Greg Nicotero and his team at KNB EFX Group would be responsible for the rest of the mechanical effects work.



Although Tippett Studio produced most of the effects, a few were assigned to other vendors to accommodate a tight production schedule. Pacific Data Images took on the film's opening- all-CG shots revealing a meteor in space and its fiery entry into the earth's atmosphere.

To ensure that all four vendors were on the same page and that consistency would be maintained, designs for all the alien creatures except the primates originated at Tippett Studio, with concept drawings, sculptures and reference materials passed to PDI and KNB for their specific assignments. Moreover, Reitman was the final decision-maker on every detail of the creatures and their habitats. Conducting weekly meetings with each of the vendors, he approved everything from concept drawings to Photoshop images to photographs to test footage.

Tippett producer Ken Kokka, along with executive producer Jules Roman and co-supervisors Brennan Doyle and Frank Petzold, spearheaded the production of the 160-plus effects shots that still resided at the Tippett facility. "Frank and Brennan and I have been working closely together for seven years," Tippett said. "We're friends, and the kind of telepathic communication that we needed for a project like this was there. Each of us has our strengths. Frank is very photographic and good at lighting, and Brennan is really strong on CG and comping. I'm more into the editorial and performance stuff. We crossed over back and forth, and I just tried to step in and make the hard decisions."

By the time vendors had been formally assigned to the show, some delivery dates were only weeks away- and, in some cases, design work had yet to be completed. "It took a lot to get the design process up and working in the beginning," remarked St. John. "We wanted to have all eighteen creatures designed and finalized before we started shooting on the nineteenth of October. We did fairly well- we were only short by about four, and one of those was the amoeba-like organism." Reitman would not sign off on the amoeba design until mid-April 2001, more than a month after the end of principal photography.

The schedule made for a highly compressed creative process, with designs still evolving even as Tippett Studio embarked on creating animatics for the major sequences and began producing final shots. In fact, as principal photography commenced, some shots were still in the concept phase, while others were already being finished. "I was running around on November 1, saying: 'You know what a big day this is for the visual effects on Evolution?'" St. John recalled. "Today,



The impact of the meteor destroys a shack where Wayne Grayis conducting an early-morning firefighting exercise. PDI digitally enhanced practical pyrotechnic elements rigged on location by special effects supervisor Burt Dalton.



Alien microorganisms released from the meteor into a cavern quickly evolve into more complex lifeforms that begin to menace the population of a nearby desert community. At a country club, a reptilian predator drags a struggling member down a slope and into the pond from which it has emerged. In animating the creature, the Tippett crew was tied to the timings of a practical rig employed on location to pull the actor down the fairway.

we are in preproduction, production and postproduction simultaneously!’ We were still designing creatures, we were shooting and we had just handed over the first sequence.”

The film begins with a sequence produced by PDI. Included in the shots were those of the alien meteor in space, its fiery entry into earth’s atmosphere, and its crash-landing in the Arizona desert, where it destroys a remote shack and plunges into an underground cavern. The sequence was based on animatics by the Tippett team. “PDI took that animatic and refined it and added some new design elements of their own,” stated Tippett, “but we supplied them with the basic artwork.”

PDI digital artist Mark Wendell was responsible for the meteor- a subject he had visited many times in his career. “I had done the meteor for the Deep Space Nine opening titles,” remarked Wendell, “and a lot of other Star Trek work. Cosmic Voyage, the Imax movie, had some comets that I worked on, too. So I had done meteors for serious, science-based projects; but the fun thing about this project was that it didn’t have to be real. I’ve worked with scientists where we really had to think about every single element and how it behaved; we had to get the timing and the look correct and compare it to real photographic reference of comets. But this was a comedy, a science fiction movie. It was all about making it look great. Who cared if the science was real or not?”

Wendell pulled together a small team and broke the assignment into two segments: the meteor approach and the meteor landing. The former starts with an image that looks like a star-field; but as it rolls past, strange parallax shifts take place, and it becomes clear that the points of light are not actually distant stars but sparkling objects on an irregular surface. “It rolls around,” explained Wendell, “and we bring in the sunlight; and you realize that you’re actually looking at a rock. As we come close on this rock, some strange, obviously nongeologic detail is revealed- organic structures that clue the audience in that this isn’t just a normal rock. Finally, the rock starts to roll away, further and further, until we see the whole thing and realize we are in space, above the earth. There are a variety of cuts as it approaches the atmosphere, starts heating up, and finally explodes into a thousand fragments, each spinning and flaming away. In the last shot, we see a big shard of rock, the size of a Winnebago, spinning down towards earth.”

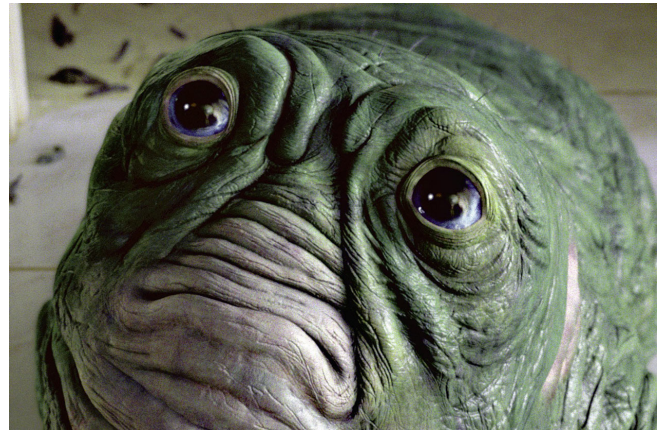
In realizing the one-hundred-percent synthetic meteor, PDI relied upon Tippett reference materials and Bartoli concept art. “Yuri would start by painting something for us,” said Wendell, “and we would try to match that. Then we would come up with additional elements- a big smoky trail coming off the meteor, a fiery element around the rock- until we had something that looked really cool.”

The descending shard continues to plummet toward earth as would-be firefighter Wayne Gray (Seann William Scott) rescues a dummy from a remote desert shack as part of a jury-rigged firefighting drill. Running from the shack, he turns and looks up to see a real emergency- the fiery meteor, hurtling straight towards him. He dives for cover just as it strikes the shack and his nearby car. Gray’s all-CG POV of the meteor’s approach required a clever cheat of perspective. “The challenge on a shot like that is the angle,” said Wendell. “If we’d used an accurate point of view, we wouldn’t have seen much of the meteor’s tail. It would have just

looked like a fireball. So we tilted it a little to look as if the meteor was coming from the upper left and at an angle, which allowed us to reveal a bit of the tail off to the side. We do that kind of thing to generate visual interest.” Burt Dalton blew up the shack and flipped the car to provide live-action elements for the meteor impact.

With the meteor lodged beneath the desert floor, Evolution’s Evolutionary cycle begins. First to appear are one- and multi-celled alien organisms created by PDI, based upon Tippett and Bartoli concept work. Those organisms quickly evolve into flatworms, another digital creation originally assigned to PDI. Early on, however, when it became obvious that PDI would not have the time or the resources to complete both the meteor sequence and the flatworms, those shots were awarded to Sony Pictures Imageworks. By the time SPI supervisor Jim Berney received the project, he had fewer than eight weeks to complete ten shots. Working with a staff of ten, he began producing shots based on Phil Tippett’s concepts, tweaking the flatworm design in the process. “We added a viscous layer on top,” recalled Berney, “a coating that was kind of cloudy and revealed glimpses of various organs. It added a lot more depth and texture. Depending on the angle, you could see through the outer tissue, and into the veins, then past the veins and farther in.”

A major concern of Reitman’s from the outset was that the motion of the digital creatures look real and organic. To achieve that, SPI employed a combination of keyframe animation and a proprietary flocking tool the company had only recently developed. Individual worms were hand-animated, then replicated into a mass of thousands through the flocking program, which assigned a random, organic movement to The Many layers of computer generated worms. Imageworks also produced images of the creatures reproducing through mitosis. “We actually got the innards of the flatworms to pull themselves apart and duplicate,” Berney explained. “They slowly divide as the membrane rips apart. It was a pretty tricky effect, particularly as we had to do it in a month.”



The invasion progresses with the discovery of a slug-like animal in the bedroom closet of a suburban home. Coaxing adequate expression out of the flat-faced ‘Cutie Pie dog’ was a major concern of the Tippett animators. After creating a library of five main expressions, animators used slider controls to segue from one to another.



Having been banned from the crash site by military personnel, Ira and Harry don protective suits and sneak back into the cave, now an eerie wonderland of alien flora and fauna. Artists at Tippett Studio scanned and digitally replicated the enormous cavern, built on a soundstage by production designer J. Michael Riva, to facilitate the interaction of their CG creatures within the environment.

In the story, Gray discovers the flatworms in the water system of the local country club where he works as pool manager; but his first major encounter with the strange lifeforms is when an aquatic leech attacks him from within a water filtration tank. The leech- designed by Tippett Studio and animated by PDI- was a mostly straightforward project for Wendell and his crew. "At first Gray hears this thump from the filter tank, which is a big glass tank of bubbling water," said Wendell. "He slowly puts his face up to it and we cut to his POV looking into the bubble, and see this odd shadowy shape. It comes forward, looks at him for a beat- then lunges at him. He jumps back, really startled, and you see it trying to get at him through the glass." Since the leech and the glass water tank were both digital images, Wendell and his crew were able to cheat the perspective to produce a more dramatic lunging effect. "In the lunging-at-the-camera gag, we cheated the perspective quite a bit. The tank was supposed to be about two and a half feet in diameter; but we put the leech farther back than that, far behind the back side of the cylinder. Then, when it emerged through the bubbles, it lunged way past the front of the glass towards camera. It made the shot much more dramatic; and you never notice the perspective is exaggerated from too far away to too close."

The Evolutionary cycle advances so quickly that yet another form- an alien amphibian- actually breaks out of the country club's water system and into the 'real' world. As conceived by Peter Konig, the 'tiphibian' was a large four-legged creature that looked like an alligator with a hairy hump and the markings and coloration of a jungle cat. The creature first appears as it surges out of a golf course lake to grab a haughty country club member and drag him into the water.

For shots of the creature leaping out and chasing after the doomed club member, the Tippett crew created a CG tiphibian. The approved tiphibian design was made into a maquette built specifically for scanning. To avoid occlusion issues- with one part of the body obscuring another part during the scan- the maquette was taken apart and scanned in sections, body part by body part, by model supervisor Ease Oweyung. Those separate sections- appearing as wire-frame pieces in the computer- were then rejoined and turned into an animation-resolution model and a high-resolution version, the latter featuring hand-painted texture maps and displacement maps for detail.

The biggest challenge for animation supervisor Eric Reynolds and his team was making the tiphibian interact properly within the live-action plate. During the filming of this plate, Burt Dalton had supplied interactive splashing effects in the pond and a roller mechanism that pulled the actor down a slope and into the water on his belly. "We were tied to the timings and the action of the rig they had used on location," noted Frank Petzold, "and the tiphibian had to move in accordance with that movement." Photographic and CG water elements were added to the plate for shots of water dripping off the emerging amphibian or to simulate its appropriate interaction with the pond.

When next seen, the tiphibian- now a foam latex prop supplied by KNB- is a lifeless mass delivered by Wayne Gray to the science department of Glen Canyon Community College, where professors Ira Kane (David Duchovny) and Harry Block (Orlando Jones) take note of its anomalous nature and set about trying to determine its origin and implications. Their efforts result in further strange discoveries. As the alien invasion spreads to the surrounding areas, a

bizarre combination of dog and slug is discovered in a housewife's closet. When the woman coaxes the sweet-looking creature out of the closet- calling it 'Cutie Pie'- it opens its mouth to reveal a second, vicious head that darts out and slams its teeth into her hand. Tippett and key members of his crew were on hand to guide the live-action shoot for the sequence- as they were for every effects scene. "Because we'd laid out the scenes in the animatics," explained Tippett, "once we got to the locations, we could say, 'The camera goes here; it needs this lens; it goes like this, bump, bump, bump.' It was all very clear."

Reference for facial behavior on the CG Cutie Pie came from the children's movie, Milo and Otis. "Milo and Otis was about a pug dog and a cat," said Eric Reynolds. "It had some awesome stuff with the pug that gave us all the looks we needed for the Cutie Pie dog- the surprised look, the angry look, the sad look. At first we thought: 'We can't pull this off. All we have is this smashed face with big eyes.' But it actually worked." A library of five main expressions was created, with animators able to segue from one to another using slider controls. Other animations included the character's wheezing action- which intensifies just before its death- and a Jello-ish body-jiggling as the portly creature stumbles out of the closet.

While these creatures menace the topside world, an entire alien environment is spawning within the desert cavern where the meteor has landed. Working with Reitman and Tippett, J. Michael Riva designed the look and the feel of the alien environment, then supervised the creation of a cavern set on soundstages at Raleigh Studios in Manhattan Beach. The end result was a full 360-degree set that had only a single small opening, required by the fire marshal. The basic set was dressed and re-dressed for three separate cavern sequences. "The first time we see the cave it's very small," explained Nancy St. John. "Then it goes to a kind of 'Alice in Wonderland' sequence, with a cheerful outer-world appearance. The third cavern looks mean and ugly, with everything dark and gloomy, black and sinister."

Since a digital version of the practical cavern would have to be created- both for scenes of CGcharacters interacting with it and for a climactic 'cavern fusion' sequence- Tippett team members surveyed and measured the set carefully to make sure they had all of the necessary information for building that environment digitally, a process that was duplicated for every set impacted by visual effects shots. Going a step farther, Tippett brought in an outside vendor that used a lidar system to scan the inside of the set down to the millimeter. "We were given enough digital information," noted Petzold, "to create a highly detailed model within which the digitized creatures could move in an entirely convincing manner."

At one point in the story, Ira and Harry- who discovered the cavern and its alien lifeforms, but have since been shut out by military and government personnel- slip through security and return to the site, now crawling with strange flora and fauna. A dragonfly-type creature buzzes around Harry, then burrows its way into his protective 'haz-mat' suit and penetrates his body. Tippett Studio created the approximately two-inch dragonfly. One of the most difficult aspects of the work was the flapping motion of the creature's wings. "The wings had to move fast and there had to be motion blur," related Brennan Doyle, "but you still had to detect the shape of the wing within that blur." On set, Burt Dalton rigged a 'tearing' effect on the back of Harry's suit when the CGI creature slips inside, while PDI did the dragonfly shape moving around within his body.

Soon after Harry and Ira are busted by the military and ousted from the site, the robust alien ecology reaches an entirely new level of sophistication. Creatures resembling a cross between a dragon and a pterodactyl escape from the cavern and fly away, only to die from the oxygen-rich air. Harry and Ira find them, dead or dying, in a desert arroyo. The scene was another combination of full-size puppets and computer animation. Scheduling had created a situation in which the practical creatures had to be completed before their CG counterparts were even started; hence, design issues of size and coloration still had not been pinned down as KNB's delivery deadline approached. "The size kept changing," stated Greg Nicotero. "One day they were eighteen feet; the next day they were twenty-two feet. Also, the Tippett guys gave us the color scheme Ivan had signed off on, and told us we had to match that; but we were building eight of these birds, and we didn't know whether there should be some variety or if they should all look exactly like the approved color scheme. We had to be in agreement about such design issues, because Tippett Studio was going to be replicating hundreds of these things in CGI." Once size and color were determined, KNB created eight full-size birds that would appear in different positions nearest the actors, with Tippett CGI filling the majority of the surrounding space. "We built them over the course of seven weeks, using rebar in the arms so we could literally bend each bird into position. We welded armatures inside them, and then we made up latex skins."

Toward the end of the sequence, a dying 'Momma bird'- a CG creation- regurgitates an egg sac from which The Next Generation is born. The gooey egg sac, big as a pumpkin, was particularly difficult to visualize and produce digitally. "Each morning we'd sit up here," remarked Eric Reynolds, "and Phil would say, 'What can we do?' One thought was that the Momma bird could just spit out a wet bird, or spit out a pod that had a hard shell that would crack. We said to Phil: 'Either of those two would be okay. Just, whatever you do, please don't make it a sac.' And of course, that's what they came back with- a sac."

The most problematic characteristic of the egg sac was the viscous goo encased inside- a particularly difficult substance to simulate digitally. "Modeling anything that's soft and squishy and translucent is tough," Reynolds explained. A two-pronged approach was ultimately required. Views of the goo within the sac were achieved by tweaking and slowing down water elements Tippett Studio had in its library, while 'stringier' shots of the goo as the creature emerges used a particle system incorporating bobbies along the edges of the



The robust alien ecology eventually produces winged dinosaur-type creatures that fly out of the cavern, only to die in earth's oxygen-rich air, which is toxic to them. Ira, Harry and Wayne approach one of the ailing creatures- a Tippett digital creation- in a desert arroyo where most of them have fallen from the sky and expired. Eight practical creature corpses built by KNB EFX Group were interspersed with hundreds of computer generated Tippett versions for wide shots of the setting.



One of the dying creatures regurgitates an egg sac from which The Next Generation is born. The

opening sac. "It was a dynamic system that used math. The animator attached points by hand- and then the software calculated what would happen to the goo when, for instance, the creature's wing lifted up and stretched the goo out."

Tippett digital team simulated the goo encased within the sac by tweaking and slowing down practical water elements and utilizing particle system software.

Emerging from the sac is an evolved pterodactyl-like alien that is able to breathe oxygen. The flying alien takes to the air in a sequence involving a CG creature composited into live helicopter plates. From the open desert, the 'Wal-Mart bird'- as it was dubbed by Tippett- proceeds to an indoor shopping mall, where it wreaks havoc by flying about, snatching up a hapless young woman and crashing through a department store window before the scientists manage to shoot it down. Wal-Mart was approached for a product placement as the department store in question, but declined. The store in the final cut is a fictional chain, but the 'Wal-Mart bird' tag stuck.

The approval process for the Wal-Mart bird was long and arduous. "It took many, many versions to come up with something that Ivan would go with," Peter Konig remembered. "The sketch of the Wal-Mart bird that he finally picked after so many passes was one that we were actually about to throw in the garbage. We learned to always bring all the stuff that we had- even the stuff we didn't particularly like."

Reitman filmed the live-action plates for the sequence in an abandoned mall in Los Angeles, working closely with Tippett and adhering to Tippett's detailed animatics of the thirty-six-shot sequence to ensure that the resulting plates would work in concert with the digital creature. As a guide during filming, a full-size cutout of the bird was rolled through the mall to demonstrate the speed and flight path of the creature. While giving the actors and extras a sense of the character's size and presence, the cutout also supplied vital information to the postproduction effects team regarding interactive lighting.

KNB produced full-size talons to carry off the woman who is picked up by the flying alien. "All the closeup flying stuff was done with this pair of arms," said Nicotero. "Burt Dalton built a steel armature that they could fish cables through. The cables would come out the underside of the bird's claws and attach to a stunt harness the actress was wearing. Alex Diaz sculpted the talons, and David Wogh built the mechanisms inside." Besides animating and compositing the digital bird into the live-action plates, Tippett Studio created a CG stunt double for wide shots of the young woman in the bird's claws.

Underground, where the wondrous alien cavern has taken on a decidedly sinister cast, we meet the next stage in alien Evolution: extraterrestrial primates. The primate design was developed at ADI, where Alec Gillis and Tom Woodruff concentrated on creating a character that was both fantastic and believable. "One thing that's a hallmark for the work that comes out of our studio," Gillis remarked, "is that no matter how outrageous the story, there have to be a certain number of elements that are believable and realistic. So even though we were doing these outer-space creatures, we still wanted to put in enough trademark features for audiences to say: 'I recognize this. There's something oddly realistic about this.' We turned to primates as our key reference, because one of our directives was that this had to be a guy in a suit." That

meant designing within the limitations of a human's bipedal form- with some cheats to make that underlying form less obvious. "We tried to make the legs look a little longer, make the arms look longer, put the head up high and make the neck long. The object was to come up with something that was strangely human, but still suggested that it came from outer space."

"We started with sketches," related Woodruff, "and met with Ivan to narrow those designs down to the ones he liked. Then we started building maquettes. Once we had maquettes done, Ivan chose a body and a head that he liked; and, in Photoshop, we combined them and completed the image of the creature." Ryan Peterson contributed considerably to the face of the creature, while Jim Kagel did body designs and Steve Koch brought the elements together in Photoshop.

Among Reitman's suggestions during the conceptual phase was that the creatures be blue in color. "At first, I thought, 'Eeew, blue apes,'" admitted Gillis. "But once we started doing the design, we realized that it really did work, especially in pale blue. Pale blue skin with pink eyelids and pink lips had a really striking look to it." Reitman also requested that the primates have large, gaping mouths with very prominent teeth; but when the suits arrived on set, the director spotted teeth that looked different from the approved design. "Ivan has a very good eye. He asked us: 'Did you change the teeth? The teeth don't look right.' And we said, 'No, we don't think the teeth have changed'- but the teeth had changed. We asked Dave Penikas, our mechanical designer, about it, and he said, 'Yeah, I had to cut some of the teeth back so I could make the jaws close.' So we had to go back and fix that."

Included in the seven separate suits made by ADI was a hero version worn in the film by Woodruff, a frequent suit performer. "That had a full-on animatronic head with silicone skin," noted Woodruff, "and it was very heavy." The final version of the hero suit required four people to operate the animatronics in the head, and included full arm extensions, with Woodruff's hands actually nestled in the creature's wrists.



Able to breath oxygen, the newly evolved pterodactyl-like alien flies from the open desert into a shopping mall nearby. A detailed animatic of the sequence, produced by Tippet, provided Reitman with crucial reference during live-action photography at an abandoned mall. To give performers a sense of the beast's presence, a full-size cutout of the winged alien was rolled through the mall, thus denoting the creature's desired speed and flight path.



As it flies through the shopping center, the beast snatches up a woman in its powerful talons. Most of the scenes employed a fully digital creature and a CG stunt double for the woman. For closeups of

The shoulders and arms were built up, and Woodruff's head was in the primate's neck, with eyeholes just below the chin. Special attention was paid to the eyes, which Reitman wanted to glow in the dark, like a wild animal's. "We had made some attempts in earlier shows with Scotchlite eyes and internally lit eyes," stated Gillis, "but they always had kind of a phony look. We decided to use metallic paints on this one, so they would reflect more like the eyes of a real animal. We gave them a very broad, flat base, so there would be a maximum area of reflectivity." The lips, made from silicone, were mechanized to snarl and lift up over huge snaggle teeth. With all of the animatronic mechanisms packed in, the hero head weighed fifteen pounds.

In addition to the hero suit, ADI fashioned three secondary suits with heads that had more limited expression. "They also had a lighter-weight skin made of foam latex instead of silicone," noted Woodruff. "The third-tier suits were basically just background suits. We cast up the skins out of our molds, did a quick paint job, and glued hair on them. The heads on those suits did not have animatronics." Initially, Woodruff and Gillis were told that the third-level primates would be seen only in silhouettes or long shots. As it turned out, however, the director was impressed enough, even with those suits, to use them in the foreground of some shots.



When the military sets off napalm bombs in the cavern, a violent fusion of energy and alien DNA creates a gigantic amoeba-like meta-organism. One of many early concept tests produced by Tippet Studio artists.



To combat the rampaging organism, Harry and Ira inject a megadose of dandruff shampoo- which contains a chemical known to be lethal to the aliens- into the underbelly of the giant amoeba through a fire hose. KNB produced a forty-by-forty-foot practical section of the amoeba for the scene. The construct was hoisted onto a truss and made to undulate through cables pulled by off-camera puppeteers.

With the alien specimens multiplying exponentially, the U.S. Army orders a napalm drop on the cavern and surrounding areas- unaware that fire accelerates the alien life cycle, rather than destroying it. As the napalm bombs explode within the cave, all The Cells of the alien lifeforms pull together into a single 'meta-organism' that bursts out of the cave, surging into the desert. Having figured out the chemical composition of the aliens- and thus, their chemical susceptibilities- Harry, Ira and Dr. Allison Reed (Julianne Moore)

team up with community college science students to inject the amoeba-like organism with a dose of selenium, a substance found in dandruff shampoo.

The sequence was shot toward the end of principal photography in the Arizona desert. But even as the shoot was wrapping up, Reitman and Tippett were still revising the look of the amoeba. "As the schedule began to snowball," Tippett recalled, "the more difficult things like the giant amoeba got pushed back- especially since nobody knew what it was. We knew what a crustacean would look like, or an amphibian or a pterodactyl bird. We could get a fix on that. But this was some amazing thing no one had ever seen before. So we took many, many paths on it. At one point, I just got out my hot-glue gun and made these tiny little five-legged blobs. We had another take where the thing was much more see-through, where you saw organelles and big cells and weird stuff in it. Eventually, Ivan opted for a much more material look, one that had a hard surface on it, kind of like a big placental slug."

Though the amoeba would be primarily a CG effect, Tippett suggested that one good-sized practical section be built to be seen in closeup, interacting directly with the actors for a key scene in which the characters get a hook-and-ladder fire truck, drive under the meta-organism, and insert a fire hose into the creature so they can pump in the lethal selenium. The closeup section was built by KNB, from a Tippett rendering. "They said, 'We want a forty-by-forty-foot section that we can get underneath and shoot,'" said Greg Nicotero. "So we brought in two suit fabricators, Connie Cadwell and Beth Hathaway, to help us make giant pie-shaped sections- a combination of foam latex and foam spandex- and quilt them together. We put peg-points every few feet along each rib of the pie, then coordinated with Burt Dalton's guys, who rented a lighting truss, the kind used for rock-and-roll shows. We attached the thing to the truss and hoisted it up, and then had twenty cable-pulls from block-and-tackles at various sections all over



Echoing an image from *It Came From Beneath the Sea*- a vintage film by stop-motion maestro and Tippett career inspiration Ray Harryhausen- a tentacle of the massive organism threatens a residential area. The scale of the amoeba required that survey data and lidar scans be used to insure its proper positioning in frame during live-action plate photography.

the top of it. We could stand off to the side and pull it, and the whole thing would flex and pulse like a living thing.” Twelve puppeteers were required to operate the amoeba rig.

In order to frame the Arizona live-action background plates for the CG giant amoeba, the Tippett location crew worked with director of photography Michael Chapman to choose the right camera angle and lens so that they could avoid excessive plate repair work and also create maximum room for postproduction camera moves. “Since the amoeba was so enormous,” remarked Frank Petzold, “we couldn’t just use a paper cutout as a framing device. I used a range finder, a compass and our survey data of the lidar location scan to determine where the amoeba would be in frame. After a few calculations, I could tell Michael Chapman exactly where the right and left feet would be.”

Even after principal photography ended in February 2001, Tippett and Reitman continued design work on the CG amoeba. “We had to imagine it dynamically,” said Tippett, “actually see it moving. And the more we did that, the more we realized that an amoeba is an abstraction. It’s not a creature like Godzilla or King Kong. It’s much more like a giant tidal wave or a Twister. It’s a force of nature.” A multi-tentacled maquette– designed by Tippett Studio partner Craig Hayes– was finally approved, then scanned to provide the basic model. For shots of the creature bursting through the desert floor, the Tippett model shop constructed a twelve-by-ten-foot landscape miniature, rigged with plates that could split open and break apart– creating the ‘hole’ from which the CG amoeba would emerge. Photographic elements of that miniature, filmed on stage under the direction of Petzold, either replaced entire location backgrounds or portions of the background for the final shots.

One of the challenges of the meta-organism sequence was selling the creature’s massive size– which varied from shot to shot, ranging from 1600 to 4000 feet across. “We found that the best way to convey that scale– in addition to having characters and vehicles in those shots– was to have the creature break frame,” said Brennan Doyle. “It would come down from the top of frame, for example, and the camera would move up as if trying to get the entire thing in frame. We also added camera shake when the creature brought down a tentacle and impacted the landscape. A creature of that size would make the entire area rumble as it moved across it.” A final technique used to impart a sense of scale was to add CG atmospheric haze to the area of the creature most distant from camera, while leaving the foreground area sharp. Flying dust, rocks and debris were added to shots of the organism moving across the desert.

Just as Evolution’s aliens had raced through a fiercely accelerated development, so, too, had those responsible for bringing the film to fruition. In the final analysis, Tippett Studio would manage to produce more than 200 effects shots in just under one year, from preproduction to premiere. But the goods were still delivered in fine form, despite the intense time pressure– and maybe even because of it. “I think the reason a lot of us got into this line of work was that we operate well under pressure,” reflected Brennan Doyle. “We’re in our best form when we’re juggling eighteen creatures.”

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